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EDITORIAL

That ignorance and juvenile delinquency are major public menaces is no reason to give support to community education and mental hygiene programs. The only reason for support will lie in the machinery that such programs can provide—machinery of which the relevance is clear and the efficiency can be demonstrated. Community prevention programs have not met these criteria. Curative mental hygiene facilities have merited support by taking responsibility for the care and treatment of the mentally ill. Preventive programs must do the same by assuming responsibility for specific educational problems.

Poor study habits in college do not in themselves produce mental illness, divorce, or suicide. Poor study habits, however, produce in many students years of nagging anxiety, repeated failure, maladaptive habits of rationalization and the learning of non-instrumental approaches to intellectual problems. In short, poor study habits add their share to the multiple causation of a mentally unhealthy community. To discover a means for assuring efficient study may not reconstruct society in one stroke, but it will be one of the steps toward that goal.

Mental hygiene programs need not be entangled in the *symptom vs. underlying cause* constructions of medical science. Teaching children to eat their vegetables and to brush their teeth does not directly attack the true underlying causes of any known physical disease. Its value for public health is nonetheless inestimable. If the community mental health agency is not in the business of curing disease, it must, first of all, take the responsibility for constructing conditions that compete with disease. Quite a different matter. A straightforward educational matter.

In short, community mental hygiene programs have no alternative but to ally themselves with educational researchers and practitioners. They have no alternative but to set aside the vague adjustment nostrums in favor of the long, slow grind of discovering means for producing good study habits, for teaching reading, teaching mothers elementary behavior principles, and the hundred other small specifics which, in their combinations, contribute to a well-adjusted society. The temptation to give grandly-wise advice to all mothers about all child-rearing problems needs to give way to the not inconsiderable task of discovering a truly effective means of seeing that all our Johnnys get toilet trained with a minimum of difficulty. The seeds must be planted one at a time, the public incantations abandoned.

The *Journal* contains no answer to the question of how to control stuttering outside the laboratory, but it does report work that marks a step along the way. Only through such specificities of a scientifically based behavior technology can the social scientist hope to make good the promises upon which his honest earnings depend.

MATHETICS: II. THE DESIGN OF TEACHING EXERCISES

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THIS IS THE FIRST of a series of attempts to translate into procedural detail the theoretical system of mathetics.[1] Here you will find an elaborate account of the mathetical model for exercises, directions for applying the model to actual subject-matter, a description of rules of procedure collateral to theory but born of experience, a discussion of lesson formats with emphasis on performance simulation, an introduction to a method of empirical modification of exercises, and many concrete illustrations.

Two things are required to make an effective lesson. One is a proper analysis and description of the thing you want to teach, the learning problems it presents as well as the logic of its structure. If the educator runs amiss here, it makes little difference how well the exercises are written. The second requirement of a good lesson is a well-designed exercise. No matter how complete the analysis of the subject-matter, if it is not translated into materials appropriate to a student, the lesson will fail—not the student. The present treatise is concerned with the second of these conditions; later papers will treat of the first.

Exercise design is the last formal task in the mathetical sequence. The law of chaining is appropriate here—that the last task in the sequence is properly the first to be learned. Exploitation of the exercise model is possible and relevant even before the earlier stages of mathetical analysis have been discussed. Understanding of the exercise model will sharpen the meaning of many prior steps in the system as they are encountered. The reader, as he proceeds to the study of prior

[1] The reader should be familiar with the introductory paper in this series (Mathetics: The Technology of Education, Vol. I, No. 1, the *Journal*). The introductory paper will be referred to as Part I in this series.

stages of analysis, will have the advantage of knowing the end toward which he is working.

Most of the examples used are actual exercises, some of which have been modified for illustration. Most have a content familiar to the reader and a relative simplicity of subject matter; this is for purposes of illustration and not because the system is inapplicable to complex problems. Later papers will illustrate exercises in more advanced subjects.

All teaching exercises have in common a limited and specific aim, which is to educe from the student a new behavior combination and to relate it to the other components of mastery. Our student is not a master of the subject because he cannot make the mastery responses on the right occasions, not because he is unable to make those responses at all. The student of long division can subtract, multiply, and estimate quotients, but he cannot do these in the correct order; the student of the electrical resistor color-code can say "230 ohms," but he is unlikely to do this solely when he looks at a resistor that has red, orange, and brown color bands; a student of law can reason that a contract is valid, but may not do so when it lacks explicit statements about conditions that the law recognizes by inference. The responses of mastery are there; we have to induce the student to make them on the proper occasions—in response to the proper stimuli. To accomplish this, an exercise has to train the student (1) under the proper stimulus, (2) to make the proper response, and (3) in consequence of this, to determine what responses he should follow through with. Stated another way, the exercise will (1) show him what, in a complex situation, are the important things a master looks for, (2) show him what the master does when he sees these things, and (3) remind him to see how he has changed the situation and what he should do next. Naturally, the exercise will supply the student with the language, specialized or not, that he can later use in the same situation to remind him what to do should he become forgetful or confused.

A mastery operant consists of an appropriate response to the relevant aspects of a situation faced by a master. We use short-hand to symbolize a mastery operant as: $S^D \longrightarrow R$. Sometimes, to distinguish one mastery operant from another, we use subscripts such as $S^D_2 \longrightarrow R_1$ or $S^D_{a\text{-}1} \longrightarrow R_a$. Similarly, we use other symbols to represent the things we put into an exercise in order to get the mastery operant estab-

lished in the student's repertory. For example, we use S^O as a symbol for anything in an exercise put there to get the student to observe the important parts of the situation (S^o means stimulus for observing), we use S^I to indicate anything we put into an exercise to tell the student what mastery response to make (S^I means instructing stimulus), and we use R^O to indicate the observing response we want the student to make when we present him with S^o (R^o mean observing response). Other shorthand symbols of the same kind are used, and they all represent the things a teaching exercise is supposed to accomplish when it is laid before a student. Closer analysis reveals important varieties of the basic stimulus and response components of an exercise, and these varieties are differentiated by such devices as subscripts and superscripts, and lower case and upper case letters. For example, lower case symbols indicate covert acts or operants and upper case letters indicate overt acts or operants ($r{\cdot}s$ and $s \longrightarrow r$ as opposed to $R{\cdot}S$ and $S \longrightarrow R$). Lower case superscripts indicate subclasses of stimuli (S^a is a part of S^O and S^p is a special kind of S^I.) The symbols should be easy to remember since they are abbreviations of words that could be used to define them.

A reader's knowledge of psychology may have biased him toward conceptions of stimulus and response not intended in this treatise. A stimulus is produced not only by little things like lights and buzzers; it may be in the form of complex configurations, an abstract quality, a pattern of events, a passage of time, the student's own response, or indeed any form that uniquely accounts for a response. And a stimulus is not a physical thing any more than are honor, economics, and law, though it will, like these, have many physical attributes. Confusion of things material and mental, or physical and behavioral, has been a principal barrier to a technology of education, and it can be a barrier to the understanding of one. Metonymy could not be avoided in this treatise without reducing its style to greater obscurity. Often a mark or a diagram in an exercise is referred to as a stimulus when, in truth, it is only a physical form especially prominent in the complex that serves as an agent for the stimulation. An event is a stimulus when it stimulates; a thousand physical forms are all one stimulus if each evokes the same response. *Response*, as the word is used here, is any reaction of the student, covert or overt. *Operant* is a name for behavior when we want

to indicate both the stimulus and the reaction to it. *Act* is a name we use to indicate both the response and the effect it has. *Reinforcer* is a name for those effects of a response that make it more likely to occur again in the same situation.

There is one distinction between physical and behavior properties that is especially vital: exercises and frames are two independent unities. An exercise is a functional unit of behavior and is defined by behavior, by what the lesson is designed to do. A frame is a structural unit defined by physical space. An exercise may cover many frames, or one frame may contain many exercises, and it is important to avoid equating exercises with a particular physical space.

FUNDAMENTALS OF EXERCISE DESIGN

Suppose we wish to design an exercise to demonstrate a new operant, which we may symbolize as $S^D_{n-1} \longrightarrow R_n$. The mathetical exercise model says that we must do two things to demonstrate this operant to a student. First, we must get him to look at and identify the stimulus. We do this by constructing some other stimulus that will evoke a response of observing the stimulus of this new operant. We may symbolize this element of the exercise model as:

$$(S^o \longrightarrow R^o) \cdot S^D_{n-1}$$

The reader who is not used to stimulus-response notation should not be intimidated; these symbols can be translated like this: the exercise should have some attention-getting and explanatory materials (S^o) that will lead the student to make the response of looking at and identifying (R^o) the situation—or stimulus—(S_{n-1}) to which he will learn to make a mastery response.

Next, our exercise must get the student to make the mastery response (R^n); therefore, it should contain some material that is already a strong stimulus for this response. Usually, a simple verbal instruction (S^I) will be sufficient to evoke the response of mastery. We symbolize the model of an introductory exercise as:

$$(S^o \longrightarrow R^o) \cdot S^D_{n-1} \text{——} (S^I \longrightarrow R_n$$

Translated again, this says: get the student to observe ($S^O \longrightarrow R^O$) the stimulus (S^D_{n-1}) and instruct him (S^I) to make the proper response (R_n). We know that if he makes the mastery response in the presence of the proper stimulus he will have completed an act of mastery, and the mastery operant will be reinforced (assuming that the effects of mastery are reinforcing to him).

We have dealt only with introducing the final operant in a sequence (or chain) of mastery. We use exactly the same process to introduce the next to the last operant in the chain ($S^D_{n-2} \longrightarrow R_{n-1}$). When the next to the last response is made, the student automatically creates the stimulus (S^D_{n-1}) for the last response (R_n); however, since there may be some loss of retention for this last response, we give the student, in the second exercise, a simple prompt (S^P) which will help him to remember the last response. With the addition of S^P the model for the second exercise becomes a bit more involved:

$$(S^O \longrightarrow R^O)\ S^D_{n-2} \text{——}\ (S^I) \longrightarrow R_{n-1}.\ S^D_{n-1} \text{——}\ (S^P) \longrightarrow R_n$$

When we introduce the third from the last operant in the chain we use the same model, but now we prompt (S^P) the next to the last operant ($S^D_{n-2} \longrightarrow R_{n-1}$) and we release ($S^L$)—and do not prompt again—the last operant. The third exercise, and every one thereafter that introduces new operants in the chain, can be symbolized in our shorthand notation as:

$$(S^o \longrightarrow R^o) \cdot S^D_{n-3} \text{——}\ (S^I) \longrightarrow R_{n-2}.S^D_{n-2} \text{——}(S^P) \longrightarrow R_{n-1}.S^D_{n-1} \text{——}(S^L) \longrightarrow R_n$$

Figs. 1, 2, and 3, dealing with long division, illustrate the use of these several stimulus components of an exercise model applied to a specific chain of mastery behavior. In each figure the completed exercise is shown with its stimulus components listed separately to help the reader locate them in the exercise. Note that the stimulus components described above account for everything in these exercises.

It is a rule of the technology that there be nothing in any exercise that cannot be accounted for—nothing superfluous or lacking technical justification.

OPERANT OF MASTERY:

S^{D}_{N-1} : PRODUCT OF DIVISOR x QUOTIENT IN PLACE UNDER DIVIDEND.

R_{N} : SUBTRACT PRODUCT FROM DIVIDEND TO GET REMAINDER.

COMPLETED EXERCISE

1. Divide 45 by 11

Here is what you do: a) Since 4 x 11 is 44, the 44 is placed under the dividend

$$\begin{array}{r} 4 \\ 11\overline{)45} \\ \underline{44} \end{array}$$

Now complete the long division:

b) Subtract 44 from 45 to get the remainder

COMPONENTS OF EXERCISE

S^{O} :

Here is what you do: a) Since 4 x 11 is 44, the 44 is placed under the dividend

S^{I} :

Now complete the long division:

b) Subtract 44 from 45 to get the remainder

S^{D}_{N-1} :

1. Divide 45 by 11

$$\begin{array}{r} 4 \\ 11\overline{)45} \\ \underline{44} \end{array}$$

Figure 1. Stimulus components of a simple mathetical exercise designed to teach the last operant in a chain of mastery (long division, over-simplified).

OPERANT OF MASTERY: $S^{D}_{N-2} \longrightarrow R_{N-1}$

S^{D}_{N-2}: QUOTIENT IN PLACE OVER DIVIDEND.

R_{N-1}: MULTIPLY DIVISOR BY QUOTIENT AND PUT PRODUCT UNDER DIVIDEND.

COMPLETED EXERCISE

2. Divide 28 by 12
Here is what you do: a) 12 goes into 28 2 whole times
b) Multiply the divisor by the quotient (12 x 2) and put the product under the dividend $\quad \begin{array}{r} 2 \\ 12\overline{)28} \end{array}$
c) Subtract to get the remainder

COMPONENTS OF EXERCISE

S^{O} : *Here is what you do:* a) 12 goes into 28 2 whole times

ALSO THE PROXIMITY OF THIS STATEMENT TO THE 2 IN THE PROBLEM IS CONSIDERED TO BE PART OF THE STIMULUS COMPLEX THAT GETS THE STUDENT TO OBSERVE S . D

S^{I} : b) Multiply the divisor by the quotient (12 x 2) and put the product under the dividend

S^{P} : c) Subtract to get the remainder

S^{D}_{N-2}: 2. Divide 28 by 12 $\quad \begin{array}{r} 2 \\ 12\overline{)28} \end{array}$

Figure 2. Stimulus components of a simple mathetical exercise designed to teach the next to the last operant in the chain of long division mastery.

OPERANT OF MASTERY: $S^{D}_{N-3} \longrightarrow R_{N-2}$

S^{D}_{N-3}: LONG DIVISION ALGORITHM SET UP.

R_{N-1}: ESTIMATE QUOTIENT AND PLACE ABOVE DIVIDEND.

COMPLETED EXERCISE

3. Divide 33 by 15

a) 15 goes into 33 <u>2</u> whole times

b) Put the 2 in place above the line

c) Multiply the divisor by the quotient and put the product in its place

$$15\overline{)33}$$

d) Complete the division

COMPONENTS OF EXERCISE

S^{O} : a) 15 goes into 33 <u>2</u> whole times

S^{I} : b) Put the 2 in place above the line

S^{P} : c) Multiply the divisor by the quotient and put the product in its place

S^{L} : d) Complete the division

S^{D}_{N-3}: 3. Divide 33 by 15

$$15\overline{)33}$$

Figure 3. Stimulus components of a simple mathetical exercise designed to teach any operant other than the last two in a chain of mastery.

The Nature of S^o:

Examine the S^o in Fig. 1. It has two separate functions. Part of this observing stimulus is a statement that says ". . . 4 × 11 is 44 . . . ." the *44* is the most relevant feature of the S^D, and this statement serves the purpose of getting the student to *identify* the nature of the S^D. When we observe something we do more than merely attend to its physical topography; we must also see it as having some identity relevant to the context in which it occurs. *44* has many identities; it is a member of the class of all even numbers containing 11 as a factor, the class of imperfect squares, etc. It is also a member of the class of products of divisor and quotient, and it is this property which matters here. We want the student's response—subtracting to get a remainder—to come under the control of the stimulus, which is a properly placed product of divisor and quotient, and we want to make certain that he generalizes this behavior. We do not want him to subtract only when the number is an imperfect square. If our observing stimulus (S^o) merely directs the student to locate the physical properties of the S^D, we risk having him respond to some irrelevant property, and he may be lost when he sees another problem of the same kind in which the S^D does not possess this irrelevant property, e.g., in which the product of quotient and divisor is an uneven number.

The rest of the S^o in Fig. 1 is in the form of a statement that says ". . . the 44 is placed under the dividend . . ." and in the form of an arrow that points to the S^D. This second part of S^o directs the student to attend to or locate the physical form of S^D. In Figs. 2 and 3 it is somewhat more difficult to separate physically the two parts of S^o, but they are nonetheless there. In Fig. 2, the statement ". . . 12 goes into 28 *2* whole times" is designed to get the student to identify the S^D (quotient in place). The designer of this exercise has estimated that the second function of S^o, which guides the student to locate the quotient, is served simply by underlining the *2* and by placing the statement in close proximity to the problem.

These two functions of S^o, getting the student (1) to identify and (2) to attend to S^D, are symbolized in stimulus-response notation as:

$$S^{o}=\begin{cases}S^{a}: & \text{a stimulus directing the student to attend to } S^{D}.\\ + & \\ S^{c}: & \text{a stimulus directing the student to identify } S^{D}.\end{cases}$$

It may help the reader to remember these if he thinks of the superscript "^{c}" as standing for the word "classify", a word analogous to identify. Both the attention-directing *and* the identifying functions of S^{o} must be fulfilled if the S^{o} is to exist; observation always requires both functions, and the exercise writer needs to take special care if he is to provide for both.

S^{I} and S^{p}:

The S^{I} and S^{p} components of an exercise are often easily designed. S^{p} is quite similar to S^{I}, and the S^{I} of one exercise is modified to become the S^{p} of the exercise that follows. Compare the S^{I} of fig. 1 with the S^{p} of fig. 2: the S^{I} of exercise #1 tells the student to subtract 44 from 45 to get the remainder; the S^{p} of exercise #2 simply tells the student to subtract to get the remainder. S^{p} is a simpler and more general instruction than S^{I}; the S^{I} is in a form sufficiently detailed and specific to insure the first occurrence of the response. If the student learns anything in one exercise, he will require less instruction to make the same response in the exercise that follows. In theory, S^{p} would be unnecessary if competition were not operating to interfere with what the student learned in the previous exercise; however, we must nearly always assume some competition. The S^{p} insures a second occurrence of the response that will give the operant additional strength to protect it from competition.

S^{p} should do more than prompt the second occurrence of the response; it should be a short, simple, and generalized, verbal statement that the student can use to prompt himself when he needs to, in the third exercise and in those that follow. For example, in exercise # 3 (Fig. 3) there is no explicit stimulus to prompt the response of subtracting to get the remainder; the student may, because of competition, be momentarily stumped when he reads "complete the long division". If the S^{D} is not sufficient to evoke immediately the response of subtracting, it may evoke the verbal response, "what am I to do now? oh, yes, *subtract*," and this covert verbal response will be sufficient to stimulate the overt act of subtracting.

When the student no longer needs the prompt its strength will fade.

Specially designed mediators can serve the function of S^P. In the first exercise for teaching a student to give the numbers that ten different colors stand for in the color-code for electrical resistors (see Part I of this series), mediators such as *penny* in "one brown *penny*" serve to strengthen the relation between *one* and *brown.* The second exercise presents the colors with the mediators, which now serve as simple prompts: "Brown (penny) ———." In the third exercise the colors are given without the mediators, but the student can supply the S^P for himself if he needs to. He will see "brown———" and if he cannot think of "one" immediately, he will find it easy to think of "penny" which in turn will have high prompt value for "one." As "brown" develops more strength to evoke "one," the S^P will become unnecessary and he will cease to use it.

Reviewing the functions of S^I and S^P, think of a single operant in a chain that we wish to bring to strength. The response for this operant will be evoked in different ways by each of the successive exercises:

Exercise # 1: Instructions (S^I) make specifically explicit the response to be made:

$$S^D_{n-1} \text{ —— } (S^I) \longrightarrow R_n$$

Exercise #2: The response is prompted (S^P) by a simple, less specific statement:

$$S^D_{n-1} \text{ —— } (S^P) \longrightarrow R_n$$

Exercise #3: No explicit prompt is given; the student is released (S^L) to complete the sequence, but he may prompt himself (r·s). (Lower-case letters refer to covert student responses) :

$$S^D_{n-1} + (S^L) \longrightarrow (r \cdot s^P) \longrightarrow R_n.$$

The mastery response: There appears to be a rather widespread confusion about the nature of responses in self-instructional lessons, a confusion easily overcome but damaging when operative. It is frequently assumed that the responses required

of the student must be overt; that a student is not responding unless he writes something on paper or makes a choice from a multiple of choices by pressing a button or turning a page. But covert responses represent behavior as well as overt ones, and indeed the most complex, frequent, and definitive responses of human beings are made covertly. In teaching we wish to involve our student actively, but this does not necessarily mean that we must require overt responses. Here is a list of the properties that seem to me reasonably expected of the student's responses:

1. They should be acts of mastery or acts that help him gain and strengthen mastery performance.
2. They should require no more energy on the part of the student than is necessary. Therefore, wherever a covert response will serve as well, an overt response should not be required.
3. They should require as little time on the student's part as possible; since overt responses usually consume more time than covert responses (I can say something to myself faster than I can write it out), covert responses are more desirable, where everything else is equal.

It is true that all self-instructional lessons require far more covert than overt responses no matter how many blanks they have for the student to fill in. And traditional textbooks are really self-instructional lessons that require very few overt responses—this being one of their more desirable features. It seems clear that the design of lessons by scientific method is not to be contrasted with textbook writing; rather it seems that the lesson designer is charged with writing better books.

One difficulty with requiring covert responses exclusively is that students are more likely to slur over the response, to make only part of it. In the third exercise for the color-code of electrical resistors (see Part I of this series) all the colors are listed with blanks for the student to write in the correct numbers. Actually it is not necessary for the student to make the number responses overtly, but an occasional student will neglect one or two of the color stimuli with some covert response such as, "I think I remember that but I'll come back to it." If he forgets to come back to that color and the operant does not gain adequate strength, he will discover this soon

enough; however, the cost in time and energy of an overt response in this exercise is so small that it probably offsets the cost of several students' having to return to the exercise. Where the response is more involved and the student does not have to commit his response to paper, he may assure himself that he remembers what to do and thereby avoid making the response at all. If this results in inadequate strength, he may waste considerable time before he is forced to return to the exercise. In some exercises that call for a lengthy response, which could be made covertly, it is enough that he manifest only the last part of the response if success depends upon his having covertly made the earlier parts. While most mathetical exercises will require them, overt responses should be kept as few and simple as possible, and are not to be automatically assumed necessary.

The S^D and the S^L: The S^D should, of course, occur in the physical form relevant to the materials of mastery. The S^D itself has two components: one is an immediate *discriminative* property and the other is a *domain* property. Look at the S^D in Fig. 1: the most immediately important part of this stimulus for the response "subtracting to get the remainder" is the number *44* or, more generally, a product placed under a dividend. It is *immediate* because the student must not make the response until the product is in its place. But the *44* is not by itself enough to serve as a stimulus; it requires the proper context, and the domain (in this case, division) to which the operant belongs must be obvious. The total domain is identified by the remaining words and numbers in the S^D, by *"1. Divide 45 by 11"* and the long division algorithm.

The domain properties of the stimulus are important because there are many domains that have similar immediate discriminative stimuli. Many readers can recall making the mistake of multiplying somewhere in the middle of an addition problem. The immediate S^Ds for adding and multiplying are very much alike, and confusion can arise when we forget what domain we are operating in. We shall refer to the domain properties of S^D as the *domain stimulus,* symbolized as $\overline{S}^D$ (read ess-dee bar). The symbol S^D will refer to either the immediate discriminative property or to the total S^D complex. Where S alone is used it will mean S^D.

S^L is simply a form of repetition of the domain stimulus, and it reminds the student to complete the chain of mastery.

In exercise #3, Fig. 3, the S^L is in the form, "complete the division"; this reinstates what the domain stimulus was designed to initiate, and as a verbal form it represents only a slight variation on the domain stimulus. Often the domain stimulus may be so strong that a specific form of S^L is unnecessary.

The stimulus components of a mathetical exercise refer to functions to be fulfilled rather than a physical format. If the same statement designed to serve as an S^a serves equally well as an S^c, when provided in context with S^D, there is no need to construct a separate physical statement. Frequently, S^D will occur in a physical form that will, itself, serve as S^a or S^c, and no additional form need be given. Remember that a stimulus is not a physical thing, though it occurs in physical space and time. A stimulus is a mental thing and should not be confused with its physical form.

Techniques of Exercise Design

No matter how well one understands the theory of the exercise model, he will have difficulty designing an exercise unless he develops a few techniques that have proven useful in practice. Our habits of presenting materials to students are in many ways incompatible with preparing a mathetical exercise. The techniques described below have little to do with the behavior of a student, but rather with the behavior of the exercise writer; these techniques may appear cumbersome and unnecessary, and to some they may seem to be an attempt by this writer to promote his own trifling work habits. Nothing could be further from the truth. The steps described below have no elegant theoretical base; they are empirically established procedures that have developed gradually from experiences of frustration by the writer and his students in their attempts to translate theory into practice. How many cooks who know just the right blend of ingredients for the stew go unappreciated because their pots are not clean and their spices not fresh? The exercise writer risks producing an impalatable mess of words and diagrams on paper if he fails to give care to procedures described here.

Step 1: The Work Setting.

Once a writer is familiar with the lesson plan, he is ready to construct an exercise. He should use large sheets of paper; this is most important. Paper about 28 in. × 18 in. is ideal and it should have a good writing and erasing surface. A supply of pencils and erasers is indispensable. There are reasons for the large sheets of paper. A finished exercise is not only a thing of words and pictures but one of pattern, of layout. The large sheet provides a writer with a surface on which he can place his words and move them about experimentally until the components of the exercise bear the proper relation to each other. Moreover, most writers' handwriting will occupy two to three times as much space as type; therefore, a large sheet of paper allows a better conception of how crowded the page will be when the exercise is committed to print. Remember, too, that an exercise may fill more than one page of a book—another reason for beginning with a page larger than that found in most books.

In the early stages of design it is a poor strategy to insist on either neatness or fine sentence structure. Attempting in the first draft to effect the final layout and wording tends to interfere with mathetical design. Provide first of all the basic exercise components in some plausible arrangement. Once this is done, neatness in layout, simplicity of language, and effectiveness of illustrations, are relatively easy to achieve. At all stages of mathetics it is more efficient to move through a series of approximations. Those who attempt to create the final product in their first trial inevitably fail to do so, and waste time and energy in the process.

Step 2: Designing the S^D.

Begin with the first operant indicated in the lesson plan. This plan will describe the operant to be demonstrated, will indicate any special strategies of mediation or sequencing, and will contain a reminder of the operants that are to be prompted and released. Fig. 4 illustrates a segment of a lesson plan for teaching the color-code for electrical resistors. The exercise writer works from a form much like this, and he would consult closely with the matheticist who prepared the plan.[1]

[1] Lesson plans will be treated in greater detail later in this series.

In the beginning, forget all the stimulus components of the exercise except the S^D; it is seldom efficient to try to conceive of the exercise as a whole. We want to begin by reducing one stimulus component to some approximately suitable form on the exercise paper. Think of these components as the building blocks of the exercise, and you can imagine that it is wise to place the foundation block in its proper aspect on the paper before attending to the blocks that make the superstructure, for their sizes and positions will depend so much on the foundation block.

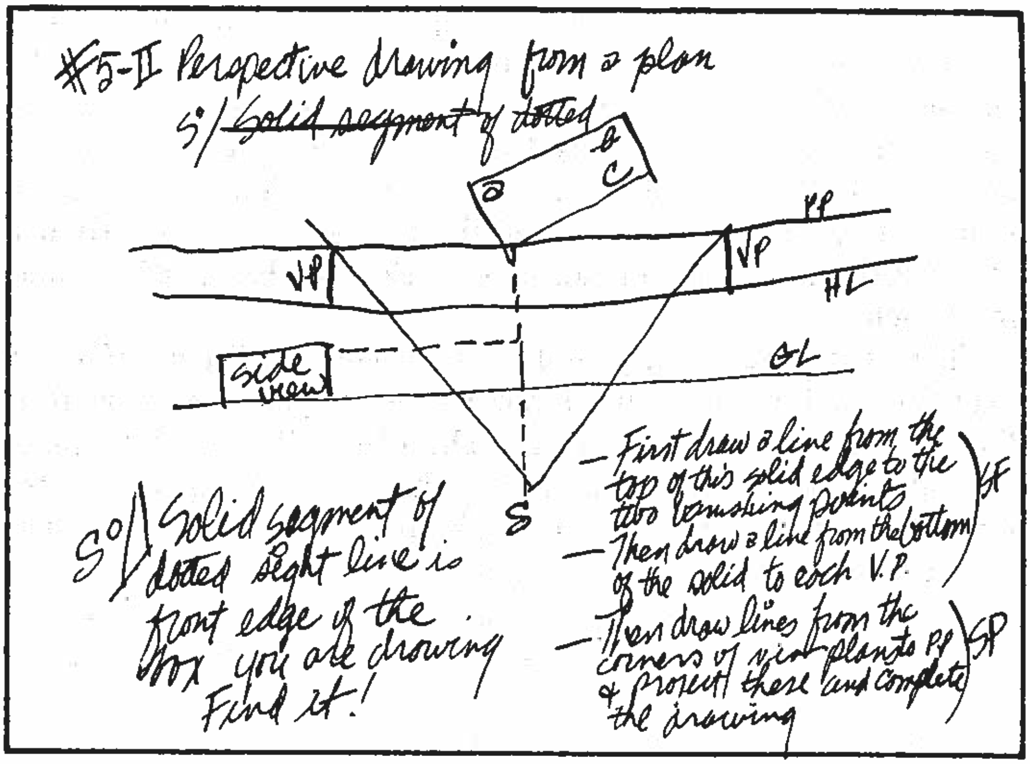
LESSON PLAN

SUBJECT Electrical Resistors TOPIC Color Code MATHETICIST JAH DATE 1-9-59

EXERCISE NO.	DEMONSTRATE	PROMPT	RELEASE	NOTES
5	$(S^D_{2.n} \longrightarrow R_{3.n})$			r·s ($\bar{D}$):
	S^D_2: Third band on			Brown – penny Black – nothingness
	resistors is one of 10			Orange – three Yellow – dog – four legs
	Colors.			Green – five dollar bill Blue – tidal fly – six legs
	R_3: Read each color as			Purple – seas – seven
	a number – the number			Gray – hair – 80 yr. old man White – CAT – lives – nine
	of zeroes added to ohms			Red – heart – two parts
	reading			
6		$(S^D_{2.n} - R_{3.n})$		Picture of resistors not
		S^P = r·s		necessary
7			$(S^D_{2.n} \to R_{3.n})$	
			Colors No. R	

Figure 4. A segment of a lesson plan from which the exercise writer works. Size reduced.

Get a mental picture of some physical topography of the S^D. Often its physical form is limited to few possibilities of variation, e.g., problems in long division. But many S^D's can be expressed in a variety of forms and we must decide which we will first experiment with. Sketch or write the first reasonably possible image onto the paper so that you may have it more clearly before you to re-shape and move about. And this is no time for perfectionism; the wordings and drawings can be



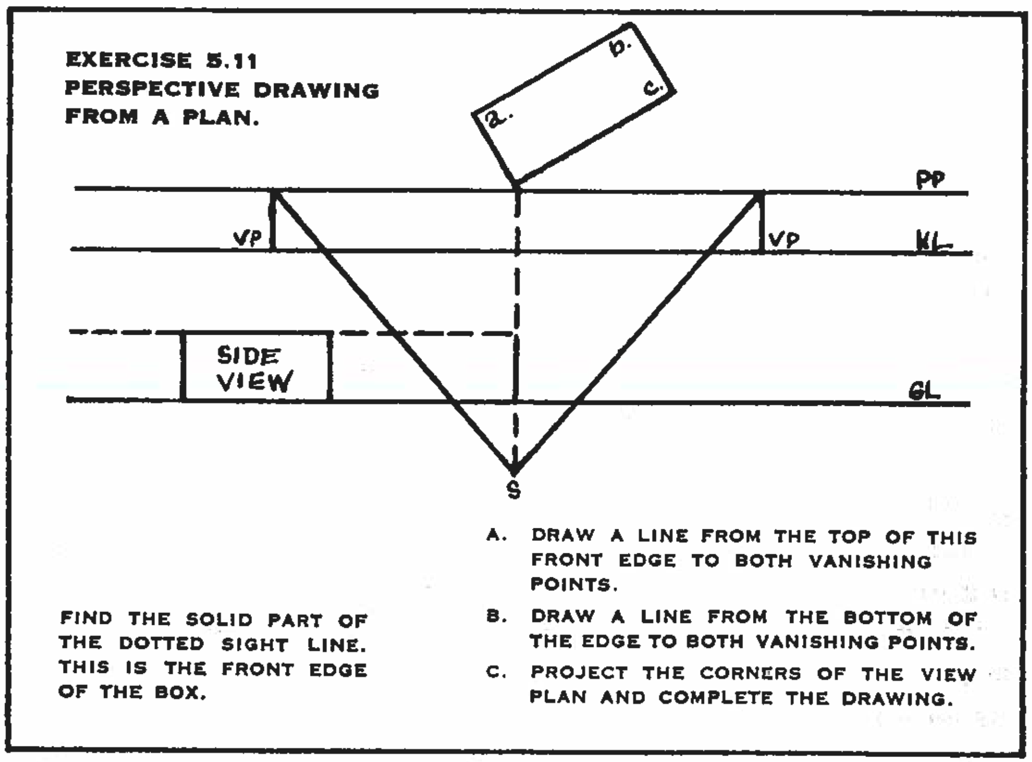


Figure 5. Reproduction of first attempt to construct an exercise, and the final copy. Reduced one-half.

shaped later into excellence, perhaps by someone even more skillful at applying finishing polish. The exercise writer works now as the artist, sketching rough, bold strokes, experimenting with form and pattern; only this work need not end in being pleasing to the eye, but graphic to the student and true to situations posed to a master of the subject. It is less than a first draft—it is the first approximation to that draft; honor it as such.

The S^D will eventually be the mental center of focus of every exercise, and while it need not be the physical center, it is likely to settle in that vicinity. Therefore, it is best to place your first attempt at constructing the S^D in the center of the large sheet of paper you are working on. Certainly it is true that the mind is biased to focus on the center of the visual frame, and it is one of the two major functions of an exercise to direct the student to focus on the S^D. By starting in the center of the page we accomplish two things: we stack the odds on the final position somewhat in our favor and, more important, we give ourselves ample room to build around this foundation in all directions.

Fig. 5 illustrates the first attempt to write an exercise and contrasts this with the exercise in its finished form. This is an exercise from a lesson designed to establish the synthetic repertory of drawing objects in perspective, from a first course in art. Notice the crudity of the exercise writer's initial effort to construct the S^D on paper, but notice its basic similarity to the topography of the final S^D. Illustrations further on will provide the reader with additional examples. It is left as an exercise for the reader to locate the forms of S^O, S^I, S^P, and S^L in the finished exercise of Fig. 5. It does not matter if the reader has little familiarity with the subject-matter.

Consider the reasons for locating the S^D before locating the other stimulus components of the exercise model. This procedure is contrary to our normal habits of constructing teaching materials, for we usually begin by talking *about* the S^D—a habit determined by our experience with students. Since the student begins an exercise by first reading the S^O, we are prone to the mistake of beginning there, too. But the exercise writer who attempts first to develop the S^O on paper, almost invariably goes astray. Imagine that you have a large sheet of blank paper before you and are ready to identify and describe the S^D: an old habit leads you to make an exhaustive verbal

description of the S^D in its physical absence. When the S^D is not represented in some form on the paper, we cannot see it as the student eventually will and, therefore, we cannot see how much of its own story it tells; we tend to say things about it that will be obvious to the student when he looks at it. Suppose we are writing an exercise to teach student clerks how to rearrange titles on file folders in the correct order for alphabetizing (for example, *John Doe* is rewritten as *Doe, John*). Fig. 6A illustrates an example of a trial construction of S^O by a writer who neglected to first construct some form of S^D on the paper; Fig. 6B illustrates construction of S^O by a writer who first sketched a trial form of S^D; and Fig. 6C is the finished form of this exercise segment. (These efforts were handwritten but have been set in type for easier reading.) Notice the unnecessary prolixity in the first effort and how close the second effort is to the final form. The S^o in Fig. 6A has about 150 words, while there are 22 in 6B and only nine in 6C. This is a rather typical result, and the differences between these two exercise writers cannot be attributed to differences in their natural verbosity. The first effort (Fig. 6A) is beginning to read like a typical textbook; its writer has initiated a lecture—the established habit of educators when other guides are missing. The second writer has the S^D before him and it has the effect of both reminding him of the simple thing he has to accomplish and allowing him to see how much of its own story the S^D tells.

Step 3: Designing the Response Form.

After the S^D is represented in some approximately reasonable form on the paper, make a provisional decision about the locus of the response and the form in which you want that response to occur. The rule here is to minimize unnecessary student effort; e.g., if it makes no difference, let him checkmark something rather than copy it; if part of the response is the addition of numbers, make the sums easy to compute; if he is learning to interpret legal contracts, which require a terminology composed of lengthy words, give him a shorthand to use.

There is a reason for deciding on a response topography and locus before you construct the S^O: the position on paper of the S^O, as well as the S^I, may be limited by the response

A: FIRST ATTEMPT TO CONSTRUCT AN S^O IN THE ABSENCE OF AN S^D

HOW TO ARRANGE GOVT. NAMES:

GOVT. NAMES ALSO MUST OFTEN BE REARRANGED BEFORE WE PLACE THEM ON FILE FOLDERS. SOME NAMES DO NOT HAVE TO BE REARRANGED. SOME WORDS IN A GOVT. NAME ARE MORE SPECIFIC, MORE IDENTIFYING THAN OTHERS AND IT IS THESE WORDS THAT ARE PLACED FIRST. FOR AN EXAMPLE, THE WORD WILDLIFE IN THE NAME DEPARTMENT OF WILDLIFE MORE SPECIFICALLY IDENTIFIES THIS AGENCY THAN THE WORD DEPARTMENT DOES; THEREFORE WE WOULD REARRANGE THIS NAME TO READ: WILDLIFE, DEPARTMENT (OF). ON THE OTHER HAND, SOME GOVT. NAMES BEGIN WITH THE WORD THAT IS MOST IDENTIFYING, SUCH AS FINANCE OFFICE. IN THESE CASES WE DO NOT REARRANGE THE NAME.

IN THE EXAMPLES THAT FOLLOW YOU WILL SEE SEVERAL GOVT. NAMES. SOME OF THEM WILL REQUIRE REARRANGING AND SOME WILL NOT. ALWAYS DETERMINE WHICH WORD IN THE GOVT. NAME IS THE MOST SPECIFICALLY IDENTIFYING—THAT TELLS THE MOST ABOUT WHAT THE AGENCY IS OR DOES.

B: FIRST CONSTRUCTION OF S^O IN THE PRESENCE OF S^D

ARRANGING GOVERNMENT NAMES:

LOOK AT THE GOVERNMENT NAMES BELOW. THE UNDERLINE WORDS ARE MORE SPECIFIC THAN THE OTHER WORDS; THEY SHOULD BE FIRST IN ORDER:

		LIKE THIS
State of Georgia	______________	*Georgia, State (of)*
Bureau of Docks	______________	*Docks, Bureau (of)*
Welfare Office	______________	*Welfare Office*

C: COMPLETED SEGMENT OF EXERCISE FOR COMPARISON

ARRANGING GOVERNMENT NAMES:

	EXAMPLES	ARRANGE LIKE THIS
1. THE WORD THAT BEST IDENTIFIES A GOVERNMENT AGENCY IS PLACED FIRST.	*State of Alabama* *Finance Division* *Bureau of Docks*	*Alabama, State (of)* *Finance Division* *Docks, Bureau (of)*

YOU ARRANGE THESE NAMES:

City of Glen Rock ______________
Department of Mines ______________
Dog Tag Office ______________

Figure 6. Taken from work sheets of a lesson on office filing.

locus (the place where the student is to express an overt response). Also, the S^I and S^O sometimes can be simultaneously effected in a single sentence or expression; these occasions are more obvious when a decision about the response is made in advance (adequate examples are provided in the various illustrations in this paper, particularly in the section to follow on the use of simulation).

Step 4: Designing the S^O.

The first rule that applies to the S^O is to keep it as simple as possible. Look at Fig. 6C; the S^o in this exercise consists entirely of three simple things: a part of a sentence "The word that best identifies a government agency . . .," the underlining of the italicized names, and the word "examples" placed above S^D; a total of nine words and a few lines. Note, too, the central position of the S^D, which is the six unarranged names. These few words and lines, aided by position, are adequate to serve the two functions of S^O; the sentence segment points to the important property of S^D (this is the S^c), and the word "examples" combines with the graphics to direct the student's attention to S^D (they serve as the S^a component of S^O). If the subject-matter of the exercise in Fig. 6C falls short of being exciting, it is nevertheless an excellent example of how the components of an exercise operate and are put together. The same principles apply regardless of the nature of the subject-matter.

Perhaps it is now clear why the placement of the S^D should precede the design of S^o and why Fig. 6A compares so unfavorably with 6B. How much do we have to say about the S^D that it does not say for itself? Once it is seen in its physical form it is easily recognized as a set of unarranged government names in each of which one word is more specifically identifying than the others. It is a reasonable bet that the function of S^c would be carried out for many students without the sentence beginning "1. The word that best . . .," that many students would induce the essential property of the S^D from the other features of the exercise. If the sentence serving as S^c were not as simple as it is we might have experimented with omitting it, for possibly all our target students could induce the principle feature of S^D without its help. Wherever it appears that the student will more than likely attend to and identify

the correct property of any S^D from its arrangement and its lesson context alone, S^a and S^c should be given no further explicit form. Always be on guard against excessive words and graphics in an exercise. When in doubt leave them out; the try-out students will let you know if they are needed.

When the S^D of an exercise is contained in a complicated stimulus complex, construction of S^a may be a challenge. Designing a really good form of S^a is an art that comes easily to some and baffles others. If special effort is needed to direct the student's attention to just the right part of an intricate configuration of words and line, success on the first trial will often depend upon outguessing the student. He is faced with a confusing jumble of detail, and in an effort to make himself quickly at home he will focus on any part of the configuration that has some familiarity, and this focus may compete directly with the focus you want. If you attempt to construct S^a in a verbal form, e.g., "look at the thing that looks like a thingumabob," you are gambling that he doesn't see the strange configuration filled with things that look like thingumabobs to him alone. If you point an arrow to the detail you have in mind, you are gambling that he does not see another configuration that includes this detail. Where is an arrow intended to point—at that which its point touches or at something immediately beyond this? If the configuration containing the immediate S^D happens to be a verbal one, the guessing game can become even more difficult. If you do not underline or italicize the key words he may not read them—an old student habit; if you emphasize too many words that are not keys to him, he may come to ignore the graphic differences.

The effectiveness of S^a depends largely upon the physical lay-out of the exercise; therefore, if the design of the S^a presents any difficulty, complete the remainder of the exercise first. Experienced technical writers and draftsmen can help with unusual cases; the best exercise writers may possess little of the art of designing good S^a's. The important thing is to keep your efforts as simple as possible and add nothing to the exercise that you are not reasonably sure is needed. The S^c component of S^0 will generally prove easy to construct if the writer follows the steps described above. The lesson plan always contains a brief description of the S^D, and often a slight modification of this description will yield an adequate S^c. Most difficulties arise when the lesson plan expresses the S^c in

a specialized language, which is sometimes adopted by the matheticist for convenience in the earlier analysis. Not infrequently the matheticist will arrive at a generalization about the subject-matter that is superior to the generalizations verbalized by experts, and he may have to improvise a modified terminology to express this broader generalization; this terminology now must be translated into a form more familiar to the student.

Step 5: Use of Specialized Mediators (r·s).

Specialized mediation, which is not inherent in other stimulus components of the exercise model, is usually inserted as the last step in creating the first draft of an exercise. This is because the lay-out and wording of *r·s* must make it easy for the student to associate it with S^D, and often this is done in connection with S^O or S^I. Simplicity and paucity of words and diagrams are as important here as elsewhere. Examples illustrate some of the variety of forms in which simple mediation forms can be presented. In Part I of this series[1], Fig. 5 provides an example. The reader should recall that specialized mediation is not always a part of an exercise, and for several reasons. Competition may not be great enough to warrant this special care, the expense of mediation design may outweigh its probable return, or sufficient mediation occurs in some other component of the exercise model. Specialized mediating forms such as those in the examples given in Part I of this series are most often used in exercises designed to strengthen multiple discriminations. In the strengthening of generalizations the S^c will usually serve as adequate mediation in a well designed lesson.

Mediation and the exercise model. In the symbolic representations of the exercise model, mediating forms were not specifically indicated. Specialized mediating forms would ordinarily constitute part or all of the S^p as the examples illustrate. But when it is necessary to design a mediating chain consisting of more than a single mediating act, a modification of the exercise model is required, though the model remains basically the same. In Fig. 13b, Part I of this series, there is an illustration of the exercise model (in schematic form) for teaching Morse

[1] *Journal of Mathetics*, Vol. I, No. 1.

code through a chain of mediating acts. Notice that in this schematic lesson plan the acts of the mediating chain are treated like the acts of a mastery chain, with one difference: in a mastery chain the student is required to perform in each exercise every act that he has previously learned, but in a mediating chain he is not required to make the mediating acts overtly once he has performed them in the exercise in which they are introduced; presumably he will perform them covertly as long as they are needed.

Differential Exercises.

The exercise model applies to the design of exercises individualized for a sub-group of the target population. A special test item (or items) is designed to select the students for whom the individualized portions of the lesson are intended. These items are relatively simple to construct since they ask of the student only that performance required in the last of the differential exercises; the test item differs from the last D-EX only in the instructions to the student. Fig. 7 is a typical test item, from an analytic lesson designed to teach the theory of balancing a teller cage. The purpose of the test item is to select those students who do not know how to manipulate a simple algebraic equation; if they cannot perform, they are directed to three exercises that teach this manipulation.

Some diagnostic items may occur at the beginning of a lesson and direct the student to another lesson ("if you are unable to work these problems you are not ready for this lesson; see the lesson entitled 'The Use of Exponents' ").

Answer Presentation.

Current schemes for designing self-instruction stress the importance of the student's checking his answers immediately after making them. It is assumed too uncritically that these answer checks constitute the student's reinforcement. Certainly he is reinforced by evidence that he has made a correct mastery response; if not, his objectives lie elsewhere. The independent answer check is not, however, the only agency for this reinforcer, nor is it the most efficient one. Theory alone requires no independent answer checks; several conditions make them practical though rarely necessary additions to a lesson.

The most immediately available source of information about the adequacy of the mastery response lies in the product of that response. To teach a child to tie his shoe laces, we properly begin by teaching him the last act in the sequence; when he makes the last response he produces a completely tied shoe, and he can see this immediately. If tying his shoes is an objective of the child, the last response is reinforced by its own doing. The first exercise used to teach shoe tying demonstrates this response and its product to the student as he observes the condition of the laces at the time the response is appropriate. In the second exercise the student is shown how to make the next to the last response, and the immediate product of this response is the condition of the laces that he previously learned to be the occasion, the S^D, for the last response. The S^D for the last response now serves to reinforce the next to the last response, and so on back through the chain. It should be obvious that no independent evidence of mastery is required by the child, that he can observe the adequacy of his performance directly as he performs.

D-17

TO LEARN THE REST OF CAGE BALANCING THEORY YOU SHOULD KNOW HOW TO MANIPULATE A SIMPLE ALGEBRAIC FORMULA. YOU MAY HAVE FORGOTTEN YOUR ALGEBRA. DO THE PROBLEM BELOW. IF YOU GET IT **COMPLETELY RIGHT** SKIP THE NEXT 3 EXERCISES.

1. IF A = B − C − D, THEN

B= ____ ____ ____

C= ____ ____ ____

Figure 7. A test item designed to select students needing special instruction before continuing the main body of the lesson.

The exercise model of mathetics is founded on the behavior principle of chaining, and this principle is derived from the principle of conditioned reinforcement; as one learns to create a reinforcing condition by responding on an occasion that permits it, that occasion itself becomes reinforcing to any responses that produce it. The exercise prompt (S^P) is a device that makes possible an even clearer connection between two sequential operants, and it can serve as an additional self reminder to the student that one or another response is correct.

Were it a noiseless world to which we apply theories, additional confirmation of correct performance would be unnecessary in self-instructional lessons, provided we honor the principles of behavior. Independent answer checks can be useful adjuncts to a lesson if they are not allowed to interfere with the self checks inherent in performance. Independent answer checks have a low order of importance and therefore should rarely weigh heavily in determining the final design of a lesson; these checks can only supplement and never replace the intrinsic self-checks, and if the latter are not operative, something has gone wrong in the original design of the lesson.

Justifications for independent answer checks. A student is unlikely to be familiar with lessons that demand—and make possible—fully accurate performance. He is so thoroughly trained to expect errors that he can scarcely believe his own self checks when they fail to reveal errors. This lack of confidence is observed, sometimes at great strength, early in a mathetical lesson, and its chief effect is to induce the student to repeat his performance unnecessarily. On occasion a student will become totally blocked and cannot continue, as though he were subject to some trick. We have observed students actually change to obviously incorrect performance, as one gives an unlikely solution to a too simple conundrum in the belief that the true solution is made obvious only to deceive him. Independent answer checks can help overcome this lack of confidence earlier in the lesson than would be possible with self checks alone. A further consequence of increasing the student's confidence is that motivation is heightened, or more correctly, some barriers to it are removed.

The student also brings other unwanted habits to a teaching lesson; almost invariably he is more careless than we intended, and he is unlikely to approach the exercises with the degree of concentration they require. The exercise components were designed with a careful and attentive student in mind, as they should have been. But the early exercises are not apt to receive this attentiveness during first exposure, the probable result being that he cannot make a response until he repeats the exercise several times. While carelessness tends to remove its own rewards, occasionally it results in a response that superficially seems to be correct. Though the student may complete one exercise with an incorrect response, he is not likely to be able to perform correctly in the second and will be

forced to repeat. This, however, consumes time that frequently can be reduced by an independent answer check. While the independent check does not provide the immediate confirmation of a correct response that the self check provides, it can give earlier indication of the careless errors found so often at the beginning of a lesson.

The inevitable imperfection of even the finest lessons offers the third reason for independent answer checks. Occasional errors in the exercises will mislead the student, and the answer sheets are additional protection against this. Typographical errors in the exercise will probably not be the same as those in the answer sheets, and if the student cannot decide which version to believe (though he usually can), he at least has a focus on the problem. More important than typographical errors are mathetical errors. Occasionally, there appears an exercise in which the S^o or the S^I functions poorly, either because its inadequacies were overlooked in try-out or because the try-out students happened to be unrepresentative with respect to that particular exercise. Where this happens, the independent answer check may give the student enough additional information to serve these functions.

Answer formats. It is not desirable to design the independent answer checks until all exercises are in the first draft, for a number of alternative answer formats are available and the choice should largely be guided by the exercise formats. There are no set forms which need or should be followed, and simplicity and convenience are important guides. The principal guides to answer format design are: (1) avoidance of distraction; there is one reason why the answers should not be clearly visible while the student is working on the exercise—it is very difficult for a student to avoid reading an answer that is clearly visible when he is working the exercise; (2) clarity in language or lay-out; (3) ease of locating and handling; (4) the economics of book making. Normally, cheating will not be a factor that determines the format; if the student cheats, either you have failed to produce adequate exercises or your students do not possess the educational objective assumed. Some cheating will occasionally occur early in the lessons simply because it is a well established habit among some groups of students, particularly at the college level. But these students will discover soon enough its futility and will

abandon it when they see that it actually adds to the amount of work required.

If the answers are in words or similar symbols, they can be placed at the bottom of the page. Further protection from distraction can be attained by printing them faintly, upside down, or in mirror image. These methods are useful where more than one exercise is on a page or more than one response is required in a single exercise, for frequently it is convenient to have the answer check located near the response locus. The literature on teaching machines and programed instruction is full of a variety of examples of these answer arrangements.

The device known as the programed textbook is essentially a means for arranging independent answer checks; it will seldom prove useful for mathetical lessons since the exercise format is greatly restricted by the answer format, a condition that should be avoided at all times. For most lessons a separate and detachable answer booklet can be placed at the end of the book. It is unnecessary to describe the many possible answer formats; the important thing is to avoid all pre-existing formulae and let the exercises and the art of book lay-out be the principal guides. Methods of controlling answer presentation where cheating is a genuine problem will be discussed in a later paper on evaluation and mental tests.

The check-list. We have argued that the student's lack of confidence in the skills that he acquires is an adequate reason for providing an independent answer check. An extension of the use of the answer check can be helpful to the student after he has acquired the skill, especially for the purpose of supporting his confidence, but also to help maintain retention during the time that immediately follows his completion of the lessons. The operants of the prescription can be printed on a pad in the form of answers and in the correct mastery sequence, with the instruction that the student check each step with a pencil as he performs it correctly. Such a check-list is made available to the student and he is not required to use it except as he feels the need. As the student's confidence in his newly acquired skill increases, he will discard the check-list until he again finds himself making errors.

Simulated Performance

Exercises designed to establish a synthetic repertory will engage the student in actual mastery performance. He must perform the operations of using an adding machine while learning how to use the device. But supplying each lesson with the materials and equipment of a job can make them expensive and bulky. Economy and convenience urge us to reduce instructional materials to a paper and pencil form wherever possible. Moreover, the requisites of mathetical teaching strategies will sometimes make the use of actual equipment absurd. To establish a three-operant behavior chain of dividing on a calculator, it would be foolish to honor the law of chaining by providing multiple calculators, the first having all but the last operation set up in the machine, the second all but the next to the last operation, and so on.

Fortunately, we can nearly always find a way to engage the student in the actual operations of mastery while using only pencil and paper and cheap cardboard constructions. We usually are able to simulate acts that require equipment; this is because most of the behavior involved in the use of equipment is already well established in the initial repertory of our target student. A high school graduate learning the mechanics of salesclerking must learn certain sequences of operations on a cash register; but he does not need a real cash register to learn these sequences, because he knows how to depress keys and push levers. In the teaching lessons it is necessary that he engage in only those behaviors of mastery that are not yet established in his repertory. If we present him a picture of a cash register and have him pencil *X* marks on the correct keys in the proper sequence and draw arrows or circles to indicate where a lever should be moved, he will be performing as a master just as surely as if he used a real register. The transfer to the mechanical device of the skill he learns with paper and pencil should be complete.

It is necessary to fulfill three conditions to insure complete transfer of a skill from the simulated to the actual situation:

a) The stimulus topographies of the two situations are similar enough to guarantee generalization. It is rarely difficult to meet this condition.
b) The response topographies of the simulated acts can

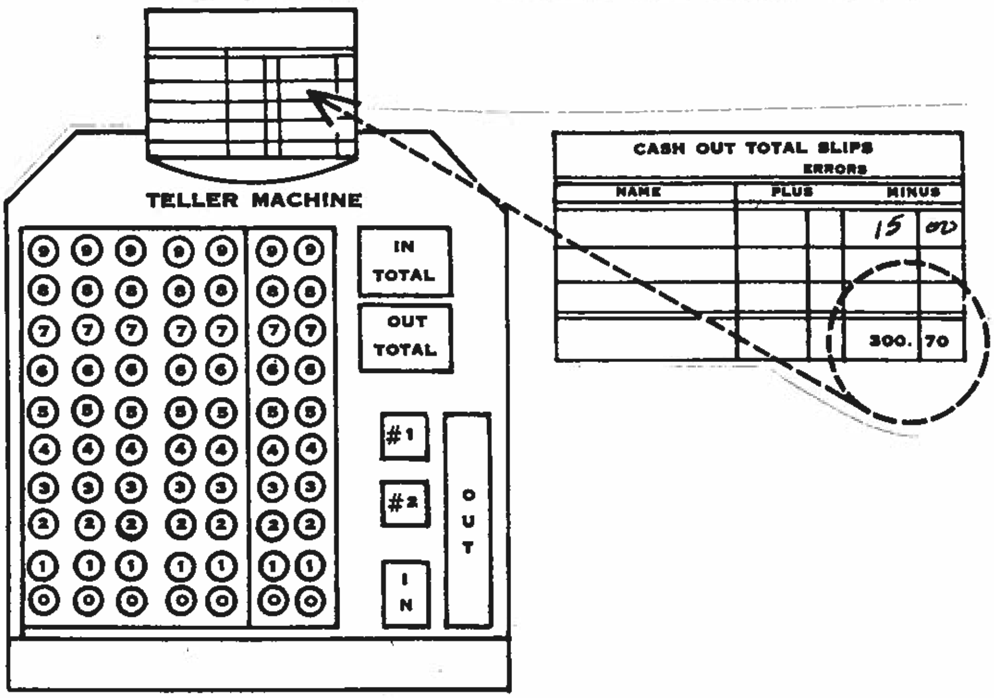
mediate the appropriate response topographies in the actual situation. We must take care to minimize the similarities of the simulated acts if we are to avoid competitive mediation. For example, suppose we have the student use a cross-mark to indicate a staple and a check-mark to indicate a paper-clip; he may later reverse the operations or use a staple on both occasions, for the two simulated acts have a history of interchangeable use. Since a check-mark resembles a staple somewhat more than a cross-mark resembles a paper-clip, the check-mark may easily mediate stapling because of induction, and the student may staple when he should clip. And if mediation fails, the student, instead of stapling, may actually pencil a check-mark on a paper in the real situation. These behaviors occur, and errors this small can make lessons appear to be failures, though only small modifications could transform them into smooth teaching instruments.

c) All the operants constituting mastery, but not established at strength in the repertory, should be required in the simulated situation. A student may later fail to move a lever necessary to operate a real device simply because the simulated materials did not teach him that the lever had to be twisted slightly before it would move. In a test of transfer, a student may appear hopelessly incompetent where, in truth, he is ignorant of only one small but crucial operation.

There is a rule of economy that applies to the design of simulated performance: where there is doubt whether the generalization necessary for transfer will occur, assume that it will; use the simplest and least expensive design you think you can possibly succeed with. There are two reasons for this rule. First, if transfer from the simple approach is not adequate, you will discover it easily enough in the try-out; but if you use a more complex approach and it succeeds, you will have no way of knowing whether a simpler method might have succeeded. Finally, lesson writers almost always underestimate the student's ability to generalize from simplified simulated situations to the more elaborate actual ones; if you are in doubt, transfer will probably occur.

7-11. BALANCING THE CASH OUT OPERATIONS

A. THE AMOUNT OF CASH GIVEN OUT DURING THE DAY IS RECORDED IN THE TELLER MACHINE. THE TELLER PUTS THE CASH OUT TOTAL SLIP IN THE MACHINE AND PRINTS THE AMOUNT ON THE SLIP BY PRESSING THE OUT TOTAL KEY.



B. FIND THE OUT TOTAL KEY ABOVE. TAKE YOUR PENCIL AND "PRESS THE KEY" BY MARKING IT WITH AN X.

C. NOW, CORRECT THE CASH-OUT TOTAL AMOUNT ON THE SLIP AND RECORD THE CORRECTED TOTAL ON YOUR TELLER STATEMENT BELOW.

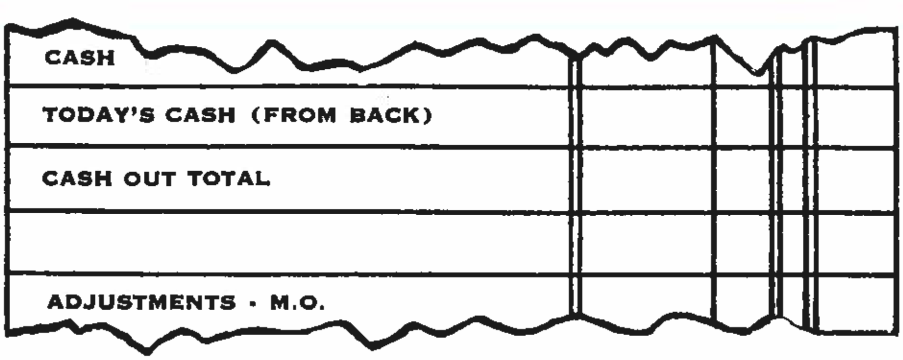


Figure 8. A single exercise taken from a lesson on commercial bank tellering. Illustrations simulation of stimuli and responses of mastery. Uneven figure at bottom is a segment of a teller statement sheet; in an earlier exercise the student would see the entire sheet. Illustration reduced one-half.

Fig. 8 illustrates a single (slightly modified) exercise taken from a lesson designed to teach bank tellers how to balance a teller cage at the end of a day. In an earlier part of this lesson the teller was shown how to simulate performance by drawing on pictures with a pencil. The cut-out at the bottom of the exercise is a part of a large accounting form; it would add needless bulk and expense to provide an actual, complete form in any but the first exercise in which it is introduced. This exercise demonstrates the operant of placing a blank cash-out record slip in the teller machine and depressing the proper key to print the total amount of cash given out. Notice that the exercise does not require the student to make an overt response of placing the slip in the machine. It is assumed that the covert act of observing the slip's position will mediate the act of placing the slip during actual performance.

Fig. 9 depicts a lesson designed to teach the mechanics of salesclerking. The lay-out can be folded easily into a box, and when unfolded it represents a simulated salesclerk station. The "cash register" has a pad of printed "register keys" on top of it. The first sheet of the pad has all the keys X-marked except those the student will learn to mark in the first exercise; the second sheet of the pad has all the keys X'd except those the student will mark in the second exercise, and so on. The "merchandise" box contains descriptions of various merchandise with their prices. As each exercise directs, the student removes a sheet from the pad and places it in the "customer" box, and records the transaction on an actual sales book. A pad of cash-register receipts is inserted in the "register" and their order corresponds with the order of the exercises. Colored envelopes are substituted for money tubes, and materials are inserted into these "tubes" and "sent" to the "tube center" by being placed in a designated spot. "Money" is in the "customer'" box and is transferred to the "register" as required. A booklet of exercises is attached to the lay-out. At the end of the lesson, if the student has performed correctly, all the "money" will be in the "register" and all the "merchandise" in the "customer box."

With such extreme simulation as appears in the salesclerk lesson, it is difficult to achieve total transfer to performance on the floor. Many variable and interfering stimuli occur in the form of customer behavior and the profusion of merchandise and materials, and immediate generalization is not likely

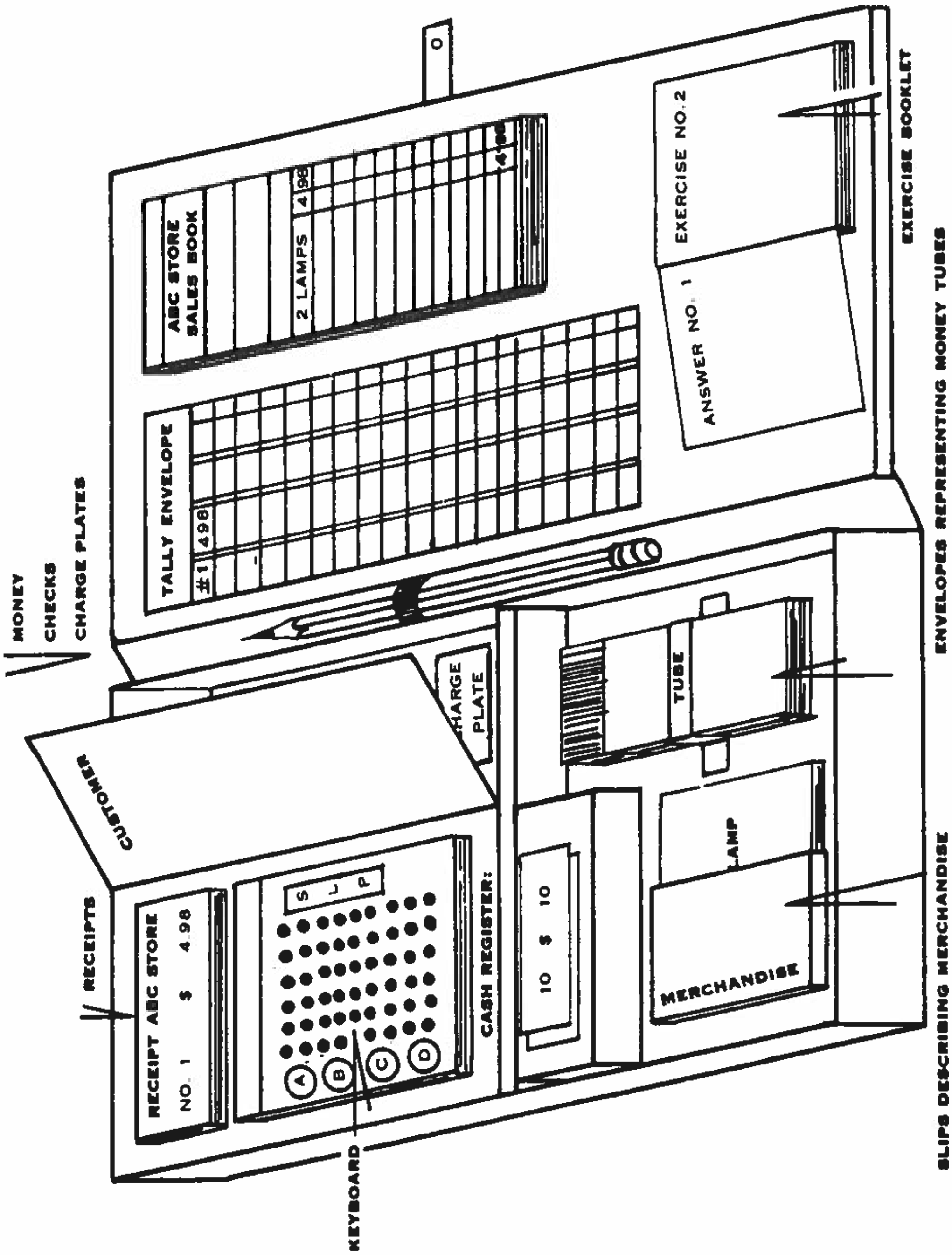


Figure 9. A lesson for teaching sales clerks the mechanics of a sales transaction, illustrating the use of a simulated field set-up.

to be total. However, the transfer will be great enough that two or three transactions on the floor will overcome the interfering stimuli. To insure total immediate transfer would require sacrificing much of the simplicity of the simulated materials, and the increased cost and inconvenience would far outweigh the slight disadvantages of having the student complete the generalization training in the actual situation.

There is the practical matter of achieving acceptance of lessons in which some transfer is sacrificed for simplicity; the matheticist is wise to include a specified adaptation experience as an integral part of his course. If the course is put to use without instructions that make clear both the necessity and the manner of follow-up experience in the actual situation, there is great danger that those who evaluate the lessons will conclude that they are worthless. If the student fails to transfer one small operant to the actual situation, he may appear to be more incompetent than he is, particularly if the outcome of that operant is crucial to success in the remainder of the lesson.

Cross-modality simulation can be useful where the actual task is expensive to reproduce in relevant sensory modalities. Suppose we are charged with training people to answer complaints and take orders over a telephone. In the actual job situation, stimuli occur primarily in the auditory modality; to reproduce these stimuli would require the use of live mock customers or recorded sound material. Painted stimuli and pencil responses, corresponding to auditory stimuli and vocal responses, are cheaper and more convenient. If one learns to read a series of customer statements and make written replies, he will be able to display the corresponding skill when he hears a customer and is required to make appropriate vocal replies.

Quite aside from factors of economy, simulated materials can be pedagogically superior to actual materials. Often the task materials are familiar in a different context, and the student may have an established habit of using them in a way that is competitive with mastery. Suppose we want to teach children to identify and name the parts of a butterfly. Where the child's habits of observing butterflies are competitive with the operants we wish to establish, the use of highly stylized diagrams will help to remove the competitive stimuli until the new operants have the strength to withstand competition.

FIND THE CONTROL PANEL ON THE TAPE UNIT DIAGRAMED BELOW:

THE CONTROL PANEL HAS A THREE-WAY SWITCH IN THE MIDDLE THAT DETERMINES WHAT OPERATION WILL BE PERFORMED AND STARTS THE UNIT. LOCATE THIS SWITCH. THE THREE POSITIONS ON THE SWITCH DO THESE THINGS:

A) TAPE CHANGE:
THE SWITCH IN THIS POSITION WILL CAUSE THE TAPE TO REWIND SO THAT THE REEL OF TAPE CAN BE CHANGED.

B) PROTECT:
IN THIS POSITION THE TAPE CAN BE READ, BUT IT IS PROTECTED FROM BEING ACCIDENTALLY WRITTEN ON.

C) PERMIT:
IN THIS POSITION THE UNIT PERMITS YOU TO WRITE ON THE TAPE.

YOU WILL INDICATE SWITCH POSITIONS BY DRAWING ARROWS. TAKE YOUR PENCIL AND DRAW AN ARROW POINTED TO THE PROTECT POSITION.

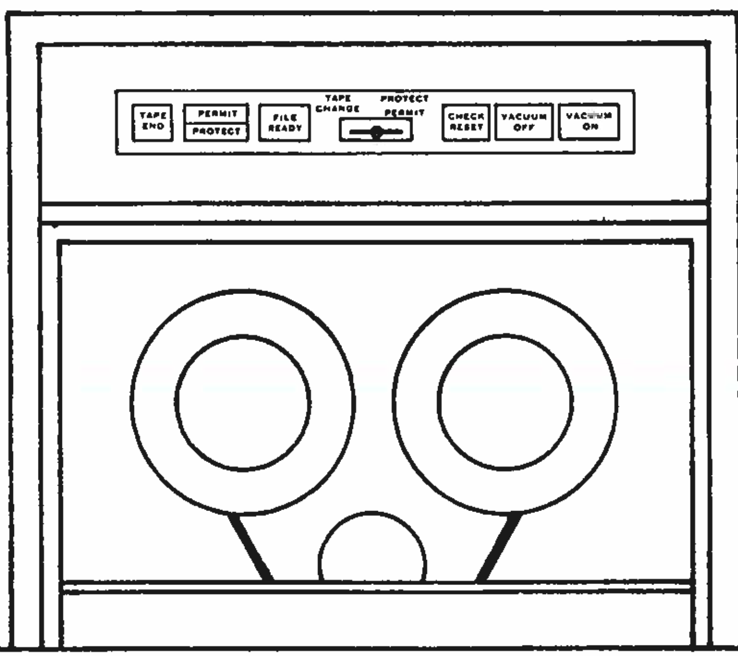


Figure 10a. An exercise from a lesson on operating a Magnetic Tape Unit of an electronic computer. Illustrates introduction of a student to simulated performance. (Original exercise 8½" x 11".) copyright © TOR Education, Inc., 1962.

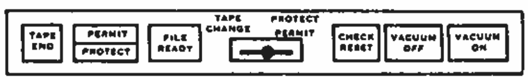
2. ON THE CONTROL PANEL BELOW THERE ARE FOUR LIGHTS ON THE LEFT SIDE. THEY ARE:

A) TAPE END:
THIS LIGHTS UP WHEN THE TAPE HAS COME TO ITS **PHYSICAL END.**

B) PERMIT:
THIS LIGHTS UP WHEN THE 3-WAY SWITCH IS IN THE PERMIT POSITION. WHEN THIS LIGHT IS ON YOU CAN WRITE ON THE TAPE.

C) PROTECT:
THIS LIGHTS UP WHEN THE SWITCH IS IN THE PROTECT POSITION. WHEN THIS LIGHT IS ON YOU CAN **READ** THE TAPE.

D) FILE READY:
THIS IS ALWAYS LIT WHENEVER THE UNIT IS READY TO READ OR WRITE. IT LIGHTS AFTER THE SWITCH STARTS THE UNIT. IF IT IS NOT LIT, THE UNIT CANNOT READ OR WRITE.



USE YOUR PENCIL AND INDICATE THAT THE 3-WAY SWITCH IS IN THE POSITION THAT ALLOWS YOU TO WRITE ON THE TAPE.

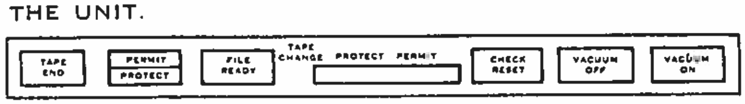
YOU WILL INDICATE THAT A LIGHT IS ON BY DRAWING A CIRCLE AROUND IT. YOU WILL INDICATE THAT A LIGHT IS OFF BY CROSSING THROUGH IT.

NOW TAKE YOUR PENCIL AND INDICATE IN THE DIAGRAM ABOVE THAT:

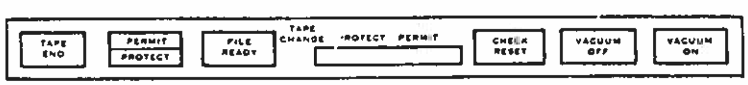
1. THE TAPE HAS NOT COME TO THE PHYSICAL END. (CROSS THROUGH THE TAPE END LIGHT.)
2. THE PERMIT LIGHT IS ON.
3. THE PROTECT LIGHT IS ON.
4. THE UNIT READY TO WRITE.

12. INDICATE SWITCH POSITIONS AND THE LIGHTS THAT ARE ON AND OFF IN THE FOLLOWING PROBLEMS.

AN EMERGENCY HAS COME UP WHILE WRITING AND YOU WANT TO STOP THE UNIT.



TAPE COMES TO THE END AFTER READING AND YOU WANT TO CHANGE TAPES.



YOU WANT TO READ ON TAPE.

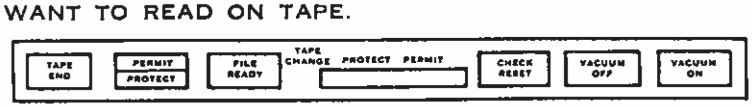


Figure 10b. 2nd and 12th exercise from lesson on operating a Magnetic Tape unit, illustrating early and late use of simulated performance. (Exercises modified for illustrative purposes.) Copyright © TOR Education, Inc., 1962.

Earlier experiences compete with learning when the student has learned to attend to stimuli that are irrelevant to acts of mastery. For example, if you begin teaching contract law by using actual contract cases, you will find that most students assign particular importance to events that have little or no bearing on the legal nature of the document. With simulated materials we may be able to remove irrelevant features until the mastery operants are at strength. It is part of the strategy of teaching a generalization that we first expose the student to those elements of the stimulus that generate the least competition with other elements.

Further examples are provided here to give the reader a more extensive picture of the range that simulation can cover. Figs. 10A and 10B illustrate exercises taken from a lesson designed to teach the operation of the magnetic tape drive in an electronic computer. Exercise #1 introduces the student to the convention for the response of moving a three-way switch to its correct position, and exercise #2 establishes the convention for noting whether indicator lights are on or off. Exercise #12 is the second half of the final exercise of this lesson. A student, after taking these exercises, would go directly to a real computer to test his transfer.

TRY-OUT AND EMPIRICAL EDITING

It is not the function of the first draft of a lesson to insure the student's success at every step. In theory, a first-draft mathetical lesson would consist of exercises that the ideal target student could seldom negotiate without help. Each operant in the prescription represents an *estimate* of largest behavior change our target student is capable of making in a single well-designed exercise—each operant is an estimate of the *operant span.* With experience, the prescription writer makes good estimates; nevertheless they are still estimates, with little probability of being perfect. Now, the economic rule the prescription writer follows is: when in doubt whether additional material can be included in an operant without exceeding the span, include the material; it is better to err in the direction of exceeding the span than to fall short of the span. This rule is based on the logic that the try-outs will easily show where the span is exceeded, but if the student negotiates

the exercise successfully it is difficult to know how far it is short of the span. Therefore, if the prescription writer followed these guides, it is likely that each exercise will include a little too much material. It is part of the function of try-out to indicate how much to shorten the span of an exercise.

Empirical evaluation is accomplished in two stages. The first is the try-out stage in which an analysis is made of the behavior of individual students working with each exercise. The second is the installation of the edited lessons into the classroom or other situation where they will normally be used.

Try-out Procedure.

The try-out is a systematic procedure. Since every word and drawing in the exercise has a known function, the purpose of the try-out is to evaluate how well each of these functions is satisfied and to discover any necessary modifications. Statistical counts of the frequency with which exercises fail are worthless in the try-out stage. If an exercise is not satisfactory, there is a reason, and it is the job of the try-out editor to rectify it. An exercise that appears hopelessly bad to an untrained observer may actually be a small step from perfection. In try-out editing we should learn to overcome the well-conditioned tendency to think in terms of success and failure; rather the try-out editor should concentrate on the specific effects the exercise has on the student.

An exercise can require modification for any combination of the following reasons:

a) The materials designed to function as S^{O}, S^{I}, S^{p}, and $r{\cdot}s$, have an effect on the student unlike, and possibly competitive with, the effect desired, or they may have no noticeable effect at all.
b) The operant span has been exceeded; the student is required to make too large a step in the direction of mastery.
c) The analytic repertory has weakened so that it is not effective in mediating the synthetic repertory.

It should be obvious that the exercise model is also the model for try-out editing. If an exercise performs the functions represented in the model, it will have to be effective; the model

states what the exercise is supposed to do, and the editor determines whether it does it. The editor clearly must know the several functions that each part of the exercise is meant to fulfill.

Step 1. The try-out setting. The try-out editor works in a private room with one student at a time. The try-out room is equipped with tables and chairs for the student and the editor. The editor should have a stop watch to record the time spent on each exercise. He will normally use a copy of the lesson booklet to make his notes in. Since the most important part of his job consists of careful observations of the student's behavior, he should have an unobstructed view. If he sits slightly to the rear and left of a right-handed student, he can observe without creating distraction. A mirror can be attached to the wall near the ceiling and tilted to reflect a front view of the student without distracting him; it can be tilted so that little of the editor's action can be seen by the sudent.

Step 2. Selecting try-out students. The first try-out student should be the try-out editor himself, even if he is a master of the subject-matter. He can take the lesson and observe his own behavior at the same time, and he will inevitably obtain valuable information about the effectiveness of the exercise components. Moreover, he will sensitize himself to many potential problems that other try-out students may have.

Formal try-out students are best obtained from a group similar to the one for which the lessons were designed. In public school groups a major difference between try-out and target students can be created by the try-out process, for it is difficult to arrange for the try-out to be clearly related to the student's educational objectives. In the first place, we are not contracting with the student to teach him anything—he may give the editor more information than the lesson gives him. And since the editor cannot pose the lesson as a necessary part of a curriculum required of the student, a major source of student motivation is missing. For this reason it is necessary to create another form of motivation. Money will usually prove effective. The student can be hired for the try-out as a job, and he should be paid for the job and not by the hour. Free volunteers can be obtained easily enough, but it is best to avoid them; often they quit when the lesson begins to demand effort, and seldom can we know their motives. The amount of

pay that a student can earn for completing the lesson should be large enough to guarantee a stable source of motivation.

Experience has indicated that the necessary number of students will vary from three to around twelve, depending upon the lesson. Students chosen from a public school group can be selected on the basis of those achievement and aptitude tests that are most relevant to the subject-matter of the lesson. It is useful to schedule the students in groups of three, representing average, superior, and inferior achievement. It will seldom be necessary to reduce the amount of material in an exercise solely because of the students who come with a poor achievement record. The poorer student may lead the editor to greater modifications in the form of the exercise components, but when these components are effectively designed the operant span of the poorer student is likely to be about the same as the span of others. The individualized exercises will provide for crucial differences in initial repertories.

S*tep 3. Instructing the student.* Introduce the student to the task by explaining that he is being used to help the lesson writers evaluate their materials and to find ways of making them more effective teaching instruments. *No specific instructions* about the lesson proper should be given to the student at the outset. Presumably the lessons are self-instructional, and if he requires instructions we should find it out. At the beginning the student is simply told to open the book and do what it tells him to do. Typically, for any number of social reasons irrelevant to the try-out procedure, the student will ask the editor what he should do, or he will read the initial instructions cursorily and ask the editor to verify his interpretation of what is required of him, or even ask the editor to explain the instructions to him. It is most important at this time not to accept the student's request for explanation. The editor should meet these early questions by referring the student back to the lesson and saying, "read the instructions carefully and do just what they say," or "the book tells you exactly what to do."

Much of the student's behavior is covert and there are only two ways of evaluating it. First, we can infer some covert behavior from the fragments that the student makes overtly; second, we can require the student to reconstruct overtly a covert sequence or to describe that sequence verbally. Since we need to avoid distracting the student any more than necessary,

it is desirable to obtain as much information from the overt fragments of his behavior as we possibly can. Only after we have exhausted this possibility do we ask the student to reconstruct or describe his actions.

For all the variety of behavior that students will display during a try-out, there appear to be only seven classes of behavior, all reasonably easy to isolate, that provide differential cues to the probable defects in the lesson. Four of these behaviors (designated Type I) are almost certain indices of defect in the lessons; the other three (designated Type II) do not necessarily indicate important defects, but they can be of considerable value in differential diagnosis.
The seven indices of defect are:

Type I

A. Failure to complete a mastery response.

B. An erroneous attempt to make a mastery response, and the editor is unable to account for the response that is made.

C. An erroneous attempt at a mastery response, and the editor can make a confident judgment that the response is made to some irrelevant property of S^D. (Example: suppose in the exercise in Fig. 6a the student rearranged all the names in a file reference in alphabetic order according to their initial letters.)

D. An erroneous attempt at a mastery response, and the editor can make a confident judgment that the response is to a well established competitive response (e.g., the student makes a response that he is obviously used to making; perhaps he treats the word *Southeast* as two separate words when he is alphabetizing).

Type II

E. The student evidences hesitation, perplexity, or repetition in reading. Overt evidence of this is easy to observe if one is watching carefully, and the overt forms may

vary from back-and-forth movements of a pencil to outright questions of the editor.

F. The student evidences boredom, fatigue, and other signs of loss of interest. It usually requires more than one exercise to differentiate important signs of this condition from the mannerisms of a completely absorbed and interested student. An occasional "damn it" may indicate a motivation level so high that the student curses himself for the most trivial and covert departures from perfection. Chronic loss of interest—or in the technical terms of operant conditioning, ratio strain—usually appears in the form of reduced energy, decrease in frequency of responding, and noticeable attention to irrelevant stimuli. Social conditioning often encourages the unmotivated student to hide more explicit evidences of his boredom—a hearty "damn it" is a sign of involvement so complete that both vigor and forgetfulness of social convention are not suppressed.

G. The student fails to follow the proper sequence intended for the components of the exercise (example: he first attends to the S^I, then reads through a list of specialized forms of mediation, etc.). This unorderly excursion over the exercise may be evidenced by hand and pencil movements, eye-movements, or verbal statements; at worst, it is evidenced by a response to S^I that is so quick that S^O and S^D could not be attended to.

Table I summarizes these indices of exercise defect and the kinds of defects they are typically associated with. The abbreviations, LO, OS, and Q need some explanation. LO refers to defective lay-out. Since the functions of the S^O and S^I are partly fulfilled by lay-out, the editor should be sensitive to the specific functions that a defect in lay-out interferes with. OS indicates that the operant span has been exceeded. This can be determined with confidence only after other defects are rectified; the operant span is defined in terms of an otherwise well constructed exercise. Q refers to quotidian variability, a term used in psychometrics to indicate the source of test unreliability associated with trivial (not test intrinsic) day-to-day variations in individual students; variance associated with temporary factors operating on the student such as illness,

TABLE 1

BEHAVIOR INDICES OF POSSIBLE EXERCISE DEFECTS FOUND IN LESSON TRY-OUTS.*

INDICATION OF PROBABLE EXERCISE DEFECTS	FACTORS FREQUENTLY DEFECTIVE	FACTORS MOST FREQUENTLY DEFECTIVE	NOTES
TYPE I. MASTERY RESPONSE. A. FAILS TO MAKE MASTERY R.	S^C, OS, Q.	$S^!$, S^P	
B. UNACCOUNTABLE ERROR IN MASTERY R.	S^A, S^C, $S^!$, S^P OS, LO, Q.		FREQUENTLY EARLY IN LESSONS DUE TO INTIIAL CARELESSNESS.
C. ERROR IN MASTERY R JUDGED TO BE CAUSED BY IRRELEVANT PROPERTY OF S^D	S^A, S^P, Q	S^C	SHOULD BE DIFFERENTIATED FROM ERRORS EVOKED BY $S^!$.
D. ERROR IN MASTERY R IS JUDGED TO BE A WELL CONDITIONED COMPETITIVE RESPONSE.	$S^!$, LO, Q	S^C, R.S (ALSO S^P WHEN IT IS A REPEAT OF THE R.S)	OFTEN DUE TO EARLY CARELESSNESS. S^D SUGGESTED WHEN S^C IS A GENERALIZATION ELEMENT; R.S SUGGESTED WHEN S^D IS PART OF A MULTIPLE.
TYPE II. OTHER RESPONSES. E. HESITATION, PERPLEXITY, REPETITION IN READING, AND EXCESSIVE TIME.	S^A, S^C, $S^!$, S^P OS, Q.	LO	RESPONSIBLE FACTOR(S) OFTEN EASY TO LOCATE WITH CAREFUL OBSERVATION.
F. PROLONGED SIGNS OF IRRITATION, FATIGUE, OR LOSS OF INTEREST.	Q	OS	IF APPEARING EARLY, INDUCEMENT IS LIKELY INADEQUATE OR STUDENT IS UNREPRESENTATIVE. IF APPEARING LATER, RATIO STRAIN INDICATED AND OS STRONGLY SUGGESTED.
G. DOES NOT FOLLOW INTENDED SEQUENCE.	S . Q	S^C, LO	MAY BE NATURAL INDICATION OF WARM-UP IN EARLY PARTS OF A LESSON.

*Symbols and other terms explained in text.

fatigue, extraordinary interest in outside events, idiosyncratic responses to some particular feature of the examination setting, etc. Q does not indicate a defect in the exercise, but defect symptoms should not be attributed to Q until other factors are ruled out. Years of test research support the conclusion that Q is unlikely to have a large effect on the total outcome of a test of reasonable length unless the factors contributing to it are unusually large: if the student is quite ill or fatigued or distracted to a noticeable degree. Differential diagnosis of Q can be made by having the student return another day, by information from the student that does not seem to be the usual excuse that students manufacture, and by failure to find the same exercise behavior repeated in other try-out students.

Experimental modifications. On the theory that the student should encounter little distraction and interruption, the examiner will gather as much information as he can from the overt fragments of the student's behavior without questioning him. When it becomes evident, however, that the student is not going to make the correct mastery response, the examiner wants to find out why. Asking the student questions can have two unfortunate effects: the question itself may bias the student to give misleading information, and questioning often places the student on the defensive and leads to irrelevant and disruptive conversation. At the first sign of reasonably certain failure the examiner should be prepared to introduce a modification in the exercise; what he is doing as he observes the student in difficulty is using the information he has at the time to formulate an hypothesis about the source of the student's trouble. If he suspects obscurity in the statement that is intended to serve as S^c, he may immediately revise that statement and present the exercise again to the student; if he suspects that S^a is not functioning because of the lay-out, he creates some modification that might overcome the deficiency. What the examiner is doing is formulating hypotheses about the reasons for difficulty and putting these hypotheses to test by modifications made on the spot. He does this with the minimal explanation to the student, simply making a modification and determining if it works. These experimental modifications may be introduced orally by the examiner, or he may make written changes on the student's exercise book. By this repeated try-out of modifications the examiner is likely to discover the source of difficulty and find its remedy. If he fails to

succeed here, after exhausting his resources, he may then query the student directly, and open-end questions may give the answer.

At the completion of the lesson, the examiner goes over the whole with the student. During this period he can obtain information valuable for making the lesson a much smoother one. The Type II indices of defect may not be so serious as to prevent the student from making the correct mastery response to the relevant properties of S^D, but they may indicate defects that significantly add to the time required for the lesson and that detract from motivation. The examiner carries out this post-lesson inquiry by going over each exercise with the student. He asks the student if he had any particular trouble with the exercise. If the student's free descriptions do not account for all of the indices of defect that the examiner has noted, he may tell the student "I noticed that you spent a lot of time reading this part over; you seemed to read it several times, and you seemed puzzled." These statements are likely to uncover more specific indications such as "Yes, I had forgotten the meaning of this word," or "When it said to do this, I thought it meant that."

The first try-out student usually provides more information than any other; he will experience most of the difficulties that students will experience with the first draft, and the modifications that are successful with the first student will often be final. The modifications should be included in the second try-out, and this can be done inexpensively by pencil changes and the insertion of a few substitute typewritten pages, without the added burden of re-constructing the entire lesson book. The try-out process is continued with the succeeding students. When is the try-out complete? When the examiner can give a confident estimate that the lesson will operate smoothly with virtually any other student of the target group, *or* when he can specify the sub-groups with which the lesson will fail in some way. Specification of lesson limitation will range from highly specific statements such as "the student must know long division" to less precise statements such as "these materials require a level of reading comprehension that some twelfth grade students (roughly estimated to be five per cent) do not possess. These students will require individual attention from a teacher in Part II, exercises 11 through 31." While any lesson can, in theory, be made completely self-instructional without

restriction, the cost of removing limitations does not always justify the effort. The fact of a limitation is revealed by the try-out examiner; he does not make the decision to remove limitations that require additional expense in analysis and design.

If the try-out examiner can state the limitations of the lessons for the primary target group, he should also be able to estimate other groups to which the lessons, or their parts, are applicable. For optimal usefulness, the lesson should include a detailed set of specifications, much like a test manual, stating:

a) Teaching objectives: what mastery the lesson is intended to produce.

b) Primary target group: a description of the population for which the lessons were primarily designed. This description is best made in terms of the crucial behaviors assumed in the initial repertory, and will not depend upon arbitrary designations (such as "twelfth grade") alone.

c) Secondary target groups: other groups for which the lesson may have value and that meet the assumptions of the initial repertory requirements.

d) Learning time: averages and ranges given by parts, with any available data about determinants of time.

e) Individualization provided: a summary of optional exercises and what they cover.

f) Empirical history: a summary of try-out groups and others in which information about the materials has been gained.

g) Restrictions and limitations: a thorough and concise statement of all known or suspected limitations, including descriptions of specific skills that the lesson establishes less than perfectly. It should be noted where there is inadequate information to determine limitations on relevant factors.

h) Special conditions of use: a description of additional equipment or materials needed, and of any unusual conditions that need to be provided if lessons are to be used successfully.

Installing a lesson. A well designed and edited lesson can be compared to a piece of industrial machinery; no matter how efficient the machine, if it is not properly installed and used it may prove worthless in operation. To insure its success, we must make certain that its operators are trained in its proper use, and that conditions exist that are optimal for its performance. The success of a teaching procedure hinges upon similar considerations; indeed, its proper installation can be even more critical for its success. This is because physical machinery is designed to produce a physical product that has a nature generally well understood by those who use the machine, while a teaching lesson produces a behavior product, and the methods classically used to evaluate this product are often indirect (mental tests). Since successful installation of a lesson has proven to require procedures more detailed than commonly thought, and because they often are at cross purposes with the mental test business, it deserves a careful account of its own. A later article in this series will be devoted to the installment and evaluation of mathetical lessons and their relation to the science of mental testing.

Summary

I. *Fundamentals of exercise design*

1. All exercises are based on the mathetical exercise model. The model expresses the functions required to establish at strength any given operant, $S^D \longrightarrow R$, in its appropriate place in a chain of mastery behavior.
2. S^o refers to those components of an exercise that get the student to observe the S^D as he makes the responses of mastery.
3. S^o has two distinctive functions. One (S^a) directs the student to attend to the S^D, and the other (S^c) identifies the essential property of the S^D.
4. S^I is any part of an exercise that instructs the student to make the mastery response. S^P is a modified form of S^I that serves to prompt the student to make the response of the operant that follows in the chain of mastery. Certain mediating acts ($r{\cdot}s$) sometimes function as S^P.

5. S^L is any part of an exercise that reminds the student to perform the operant of mastery that was prompted in the previous exercise.
6. S^D has an immediate discriminative property (that part of S^D created by the immediately previous response in the mastery chain) and a domain property (that property of S^D in effect at the very beginning of a chain of mastery and at every stage thereafter).
7. Covert expressions of mastery responses should be required only when overt expressions are not reliable.

II. *Techniques of exercise design*

1. Always begin designing an exercise on a large sheet of paper; 28 in. × 18 in. is a good size.
2. Do not insist on neatness of lay-out or clarity of sentence structure until the first draft is complete.
3. Working from a lesson plan, begin by designing the physical form of the S^D, usually in the middle of the page.
4. Next, make a provisional decision about the locus of the mastery response and design the lay-out of that locus. Then design S^I.
5. Design the simplest form of S^0 remembering that both S^a and S^c are behavior functions and not specific physical structures. Avoid using any words or diagrams that you are not reasonably sure are needed, unless they are negligible additions to the complexity and length of the exercise.
6. Specialized mediation forms are the last components of the exercise to be designed.
7. Differential exercises are written according to the exercise model.
8. Answer checks are supplemental; the true immediate reinforcer is the product of the student's own response—a self-check.
9. Answer checks are provided (a) to increase student confidence, (b) to compete with careless study habits early in the lesson, and (c) to serve as a check against possible errors in the lessons.

10. Answer formats should be designed only after the exercise formats have been determined; the former should never determine the latter.

III. *Simulated performance*

1. Simulation is desirable where the use of actual materials is less economical or less convenient.
2. Simulation is desirable to the extent that well established responses to the appropriate stimuli of the actual situation exist to compete with mastery responses.
3. Simulation is desirable to the extent that there are well established responses of attending to inappropriate stimuli in the actual situation.
4. Transfer of skill from simulated to actual situations will occur to the extent that the stimulus topographies of the two situations are similar.
5. Transfer will occur to the extent that simulated acts can mediate the acts appropriate to the actual situation.
6. Transfer will occur to the extent that one simulated act does not induce competitive mediation in another.
7. Transfer will occur to the extent that the operants of the prescribed domain of mastery are represented in the simulated situation.
8. When in doubt whether a simple method of simulation will provide the desired amount of transfer, decide in favor of the method if more certain methods are significantly less economical.
9. Simulation that provides for total transfer may not represent the best strategy. The combined costs (however calculated) of incomplete simulation and the follow-up may be less than the cost of a simulation method that guarantees total transfer.
10. Traditional tests may indicate little or no transfer even where it is nearly total. The failure of a single operant to transfer may conceal the transfer strength of other operants.

IV. *Try-out and empirical editing*

1. First draft exercises are not expected to succeed with try-out students. Purpose of try-out is not to determine whether the exercises succeed or fail, but to discover what changes are necessary to make them succeed.
2. The exercise model is the try-out guide. Exercises will need modification only when (a) the exercise model components are not functioning properly, (b) the operant span is exceeded, or (c) the analytic repertory has weakened and is not mediating the synthetic repertory.
3. The try-out examiner works with one student at a time; he is his own best first subject.
4. Try-out students are obtained from a group representative of the target students, and they are paid for completing the lesson.
5. Initially, the try-out student is given no specific instructions about the lessons themselves.
6. The examiner notes seven indices of exercise failure. He produces experimental modifications in an exercise when it is clear that the student will not succeed. Type I indices require that these modifications be made during the lesson.
7. A post-lesson inquiry is made, particularly directed by Type II indices.
8. Specifications of the lesson are written.

THE MAINTENANCE OF ONGOING FLUENT VERBAL BEHAVIOR AND STUTTERING[1]

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FLUENT speech is such a characteristic human pattern, and occurs so automatically, that we seldom realize it is under stimulus control. Like other operant behaviors, verbal behavior is produced and maintained by stimulus conditions. Moreover, any breakdown or pathology in fluent speech may reveal the nature of the relevant controlling stimuli. Consequently a study of the anomalies may provide insight into the conditions maintaining the more typical patterns.

This is an investigation of the stimuli that maintain both ongoing fluent speech and the breakdown in fluency known as stuttering. Experimental analysis of changes in behavior that occur when the controlling stimulus is manipulated are used to evaluate the role of the stimulus. Emphasis is on the control of behavior rather than on prediction; accordingly, such an analysis may lead us to understand how to control the undesirable behaviors called stuttering.

This study differs from many in this area in utilizing experimental analysis of controlling variables.

1. *Long term analysis and development of fluent and non-fluent verbal communication.* In a statistical analysis, groups

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[1] Based on a paper read at the Third Annual Behavioral Science Symposium, University of Virginia, March, 1961, Arthur Bachrach, Chairman: "The Maintenance of Ongoing Verbal Behavior." Also based on these publications by the Air Force Cambridge Research Center: Goldiamond, I. Blocked speech communication and delayed feed-back: an experimental analysis. AFCCDD, *TR* 60-37; Goldiamond, I. The temporal development of fluent and blocked speech communication. AFCCDD, *TR* 60-38.

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of subjects may be differentiated on the basis of a variable, and run for equal and limited periods. On the other hand, in experimental analysis one subject may be run for an extended period of time, while the effects of the stimuli introduced are measured by systematic changes in behavior. Therefore a base line (a characteristic pattern) must first be established, against which changes can be gauged. In this study, experimental manipulation began after the base line had stabilized. The base line measures of speech provide data on the temporal development of fluencies and non-fluencies.

A further characteristic of such an experimental analysis is that it facilitates the distinction between transient and steady-state effects. For example, certain of the disruptions reported to characterize delayed auditory feedback turned out to be functions of the limited periods used in the statistical studies, and hence were transient rather than steady-state characteristics of the phenomenon. Furthermore, the adaptation effect in stuttering turned out to have different transient and steady-state characteristics.

Some subjects were run for 9 months, 5 days a week, 90 minutes a day. Daily records were kept of the fluency and non-fluency rates, and cumulative recorders were used to assess the changing relations between the rates of each as they occurred.

2. *Use of delayed feedback as a response-contingent consequence.* In the typical delayed side-tone experiments, a lengthy period of delay is introduced and compared with normal side-tone. In this experiment, a delayed side-tone was presented or eliminated, depending upon whether or not a stuttering response had occurred. In other words, presentation of delayed side-tone was contingent upon stuttering. These conditions (and noncontingent delay) had markedly different effects upon response patterns.

3. *Operant conditioning of formal classes of verbal behavior.* Recently, experimenters have been investigating operant control over *content* of speech (Krasner, 1958). One difficulty of such research has been an explicit definition of the various content classes to which the consequences have been applied (e.g., Azrin, Holz, Ulrich, & Goldiamond, 1961). Such difficulty may be alleviated if *formal* properties of speech, such as intensity, band-width, and duration and rate of pauses and

phonations are used. Thus, stuttering is a useful pattern to study, because it is a pathology of the formal aspects of speech rather than a pathology of content. It is quite different, for example, from aphasic or schizophrenic speech.

Most investigators of the formal properties of speech have attempted to specify them in physical terms; and, often, they constructed simulating machines (Delattre, Cooper, Liberman, & Gerstman, 1956). The present investigation uses the rationale of such explicit analytic procedures, but differs from them in that it is concerned with an experimental analysis of verbal behavior rather than a physical description of its components.

Part of the control achieved in laboratory research is made possible by the formal definitions of the responses studied, as, for example, a peck or bar press that closes a relay. Indeed, such definability has often been a criterion for selecting the responses to be controlled. These procedures, extended to speech, may lend themselves to an experimental analysis and control of verbal behavior in a way that is currently not so feasible for the experimental analysis and control of the content as for the form of speech.

Operant control of chirping has been demonstrated for chickens (Lane, 1960) and budgerigars (Ginsburg, 1960). Infant vocalizations have also been controlled by varying adult social reinforcers (Rheingold, Gewirtz, & Ross, 1959). Lane (1960) brought the sound "oo" under the same control as the button press in the Holland observing apparatus, and Starkweather (1960) reports the use of a voice-operated relay to control phonation rate. Isaacs, Thomas, and Goldiamond (1960) have reported the use of operant shaping procedures to reinstate verbal behavior in psychotics who had been mute for many years.

In the area of stuttering, Flanagan, Goldiamond, and Azrin (1958) reported that when the presentation of a loud blast of noise was made contingent upon a moment of stuttering, the ratio between reading rate and stuttering rate rose considerably, but when elimination of noise was made contingent upon stuttering the effect was just the opposite. The same authors (1959) reported having induced marked blocking in a normally fluent subject through negative reinforcement, or escape from shock. Using similar procedures, Bilger and Seaks (1959) also reported blocking in normally fluent subjects.

Rational of the Present Study

Studies by the writer demonstrate that because vocalizations, nonfluencies, and other speech patterns can be manipulated by operant stimulus alteration, they can be considered operant responses. This report summarizes a group of investigations extending these demonstrations of operant control to an experimental analysis.

Use of Delayed Side-tone

The prolonged use of noise and shock for human subjects, at least, is contraindicated; but delayed side-tone (delayed feedback) provides no such potentially noxious stimulation. In delayed side-tone, the subject's voice is recorded on one head of a recorder, and his voice is transmitted to him from another head; the tape speed and distance between the heads determine the delay.

Fairbanks (1955) and Black (1959) have reported that delayed feedback disrupts verbal behavior in a variety of ways. In speech, each verbal response produces an auditory stimulus almost immediately. This stimulus is then followed by another response, which becomes another stimulus, and so on. The stimulus produced is contingent upon the response; that is, it will not occur without it. It may also occasion the next response. Such a stimulus-response relationship is defined as *chaining* (Keller & Schoenfeld, 1950). Delayed side-tone disrupts the temporal relationship that usually exists when speech occurs; and the disruptions in behavior that are produced may be functions of this change in the stimulus conditions under which speech has been established. The delayed side-tone is, therefore, useful in the experimental analysis of such conditions, and it has possible use in establishing new patterns of behavior.

Delayed side-tone has another consequence of note. Chains in which the response automatically produces a stimulus have been difficult to control because the stimulus, the independent variable, is under the control of the response, the dependent variable; consequently, the independent variable loses its independence. In delayed side-tone, these two functions are separated, and the experimenter can introduce the stimulus at will, thereby making it an independent variable.

An attempt was made to manipulate stuttering rate by applying such delayed feedback, or eliminating it, as a response-contingent consequence. The procedures were applied as well to normally fluent subjects, both to manipulate blockage rate and reading rate. Further studies were run to investigate the role of response-produced auditory stimuli in the maintenance of verbal behavior in normally fluent subjects.

Basic Method and Procedures

General

Each daily session was 90 minutes and was conducted in a specially constructed, sound-treated cubicle in the laboratory. As the *S* read from printed pages, a monitor listened to his speech and pressed a microswitch for each word during which a moment of stuttering occurred. This was recorded on a cumulative recorder. He also followed the subject's reading in a book of his own, in which a slash mark appeared every 100 words. A microswitch was pressed at each mark, recorded on the event marker. During most of the sessions, the subject also recorded each of his nonfluencies by pressing a microswitch, and such a response activated whatever contingencies were attached to the response. Sessions were taped, and another monitor at a later date monitored the tape and book for both nonfluencies and reading rate. Thus, there were at least two, and more often three, independent definitions of each session.

Material Read

Initially, a philosophy book was used, but *War and Peace* was subsequently chosen because of its length and probable novelty to the students. To maintain author continuity, *Anna Karenina*, *Short Novels of Tolstoy*, and *Tales of Courage and Conflict* were also used.

Subjects

Four male college students who had a long history of stuttering and had been clinically classified as stutterers served as subjects. They were not under therapy at the time.

Each subject's own records dictated when the various experimental procedures would be used. Subjects K and Z began late October, 1959, and Subjects L and S in January, 1960. After stabilization had occurred, subject definition was introduced; for Subjects L, K, and Z, it was withdrawn and then reintroduced, after which it was continually present. For Subject L, a period of nonresponse-contingent delay was introduced, followed by normal side-tone; and, then, a period of delayed side-tone was made contingent upon stuttering responses. After stabilization, Subject S was presented with continual delayed side-tone, with each stuttering response shutting it off for a period. After stabilization on this schedule, normal side-tone was introduced, followed by delayed side-tone contingent upon a blockage, followed by schedules in which the procedures were mixed within a session. For Subjects K and Z, the first experimental condition introduced after stabilization was delayed side-tone contingent upon stuttering, followed by normal side-tone. For Subject K, this was followed by continual delayed side-tone, with stuttering eliminating it; and for Subject Z, presentation of delayed side-tone was made contingent upon stuttering. Interspersed schedules were introduced at a later date.

Subjects were paid at the rate of $4.00 a day (or $80.00 a month). In addition, a bonus of $20.00 a month was offered if they showed up promptly and missed no sessions, for whatever reason (tornadoes and death not excepted). This procedure was so effective that only one subject lost his bonus during one month.

Subjects were instructed to read aloud into the microphone before them in the way normally necessary for sustained steady reading. During the periods of subject definition, they were instructed to press the button for each word they stuttered. There was a brief session with each to obtain agreement on the definition of stuttering; similar sessions were held with the monitors.

Normal subjects. Normally fluent subjects were run under similar conditions.

Equipment

The subject sat at a table-high counter stretching across a 4 x 5-foot cubicle painted neutral gray. A ventilating blower

effectively masked outside noises. A mirror above the counter served as a one-way screen.

The subjects wore Telephonic TDH-39 (10-ohm) earphones, and spoke into a dynamic microphone with linear response characteristics for 60-15,000 cps. Before March 8, a Presto Tape Recorder, Model SR-27, provided delayed feedback of 0.28-second delay.

In experiments requiring equal levels between direct (not delayed) and delayed auditory feedback, an additional amplifier must be used on one of these lines. In order to keep from running out of tape, a continuous loop was made by splicing together the ends of a loop about 4 feet long. Because the loop presented differing resistances to motion, the fidelity, flutter, and wow specifications are not applicable. The performance data for the SR-27 were: frequency response, uniform from 50-15,000 cps; signal-noise ratio better than 50 db; flutter, 0.25% rms at 7½ ips.

An Ampex 601, which became available March 8 and was substituted for the SR-27, met or surpassed the latter specifications. The tape speed was 7½ ips, and the head space of approximately 1.10 inches yielded a delay calibrated to be 0.20 second by a Hewlett-Packard Timer.

Delay of feedback was presented to subjects at an intensity level judged sufficient to overcome bone conduction, and was similar to nondelayed input. Reliability tapes were recorded on a Wollensak Model T-1500. Recording and scheduling equipment was commercially available Grason-Stadler equipment, with its own 28-volt D.C. power supply source.

Reliability of Definition

Given two or three definitions of stuttering, the problem of reliability immediately arises. The definition of nonfluency may be affected by a variety of variables, including knowledge by the subject that conditions producing nonfluency are being used (Hanley & Tiffany, 1954).

One approach involves the use of a correlation coefficient. Another involves analysis of the data through similar functional relations. Let us assume that two monitors define stuttering responses differently, one finding 1000, and the other, 2000 for the same sample of speech. A depressant variable

Results: Stuttering Subjects

is now introduced, and the definitions now give 600 and 1200. The variable is removed and the definitions give 1200 and 2400. Although the definitions differ markedly, *the functional relations are reliable,* and the effects of the variable can be validly assessed. The extent to which this procedure was successful may be seen in the results curves themselves.

Since the results will be presented in the form of actual records obtained from the cumulative recorder, a few words about reading the curves may be necessary.

The recording paper moves at a constant rate, and the pens produce a horizontal line as the paper rolls by. Whenever stuttering occurs, an impulse is delivered to the recorder. The pen that records stuttering moves up a small amount with each impulse, resetting after every 500 responses by making a complete excursion to the bottom of the recorder. If response rate is high, the pen will climb rapidly to the top before resetting, producing a line with a steep slope. Another way of judging rate is by the distance between reset excursions, a short average distance indicating high response rate. Because each session is exactly 90 minutes long, the number of excursions is also indicative of response rate.

Subject Definition

It will be recalled that the subject's response supplied the contingencies. The effects that the subject's awareness of his own stuttering has upon blockage have received some experimental attention (Wingate, 1959), mainly concerned with his expectations of stuttering (Johnson, 1955). If definition by the subject affects stuttering rate, any generalizations to conditions under which subject definition occurred are limited.

Figures 1a and 1b are typical response curves on subject definitions made by the *observing monitor*. These records indicate whether stuttering rate has changed.

For Subject Z, the records are markedly similar, whether they are taken before, during first and last days of, or on the day after subject definition. For Subject S, curves before and during such definition are similar. For Subject K, three typical curves without subject definition are presented, and these would appear to come from the same population as the subject

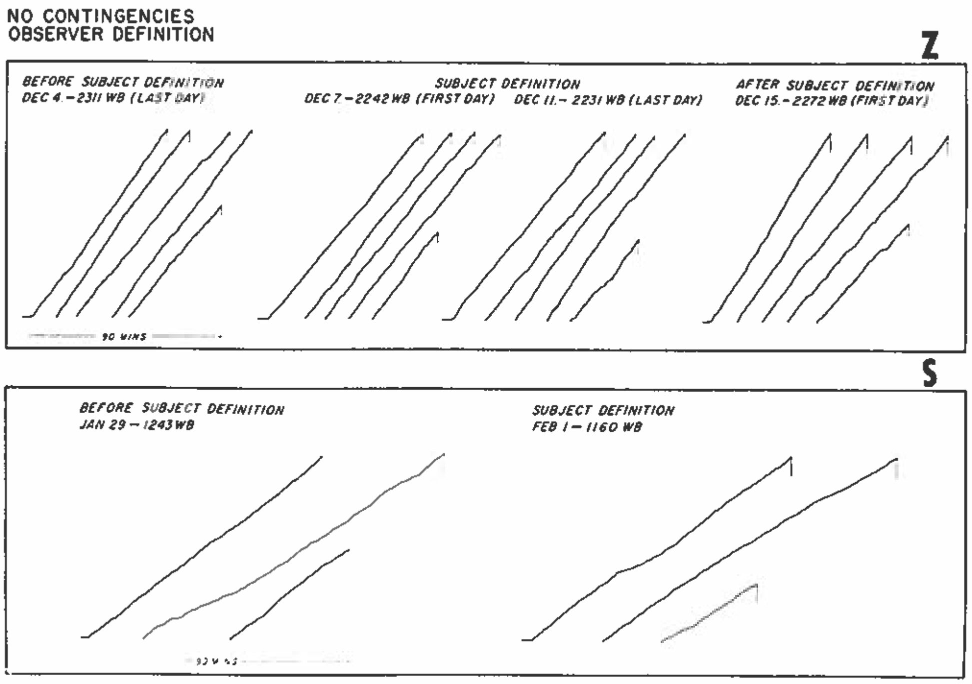

Fig. 1a. Effects upon stuttering rate for Subjects Z and S when the subject defines his own blocks. Records are by observer.

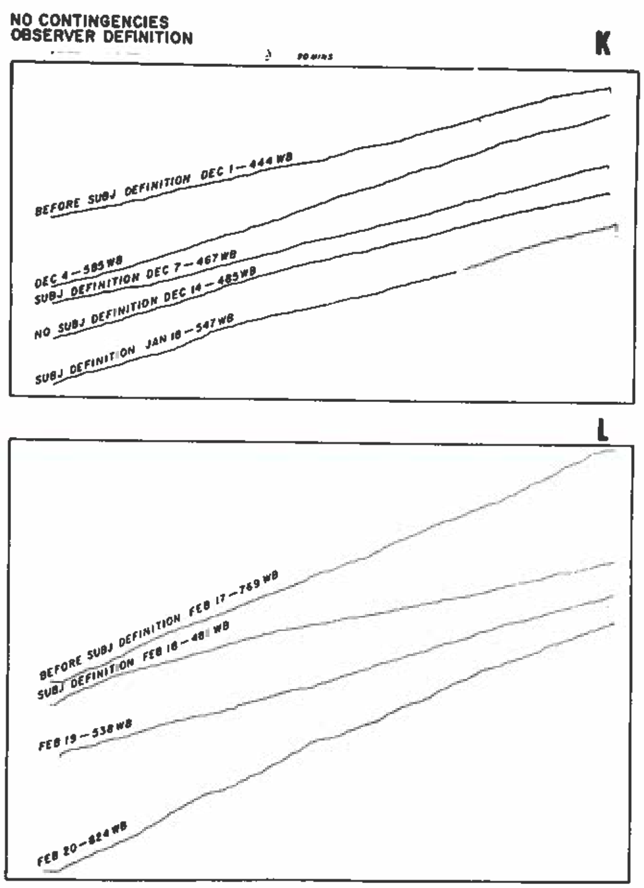

Fig. 1b. Effects upon stuttering rate for Subjects K and L when the subject defines his own blocks. Records are by observer.

definition curves. For Subject L, the immediate effect of subject definition seemed to be an attenuation of response, but this was followed by recovery.

These data suggest that having the subject define his response need not affect blockage rate; in the one exception, the effects were transitory.

The Response Controlled by Contingencies

If curves change when contingencies are applied, it might be argued that the button presses are being affected rather than the blockages they are supposed to define. Accordingly, when contingencies are introduced, curves of observer definition and subject definition will be presented, because the ob-

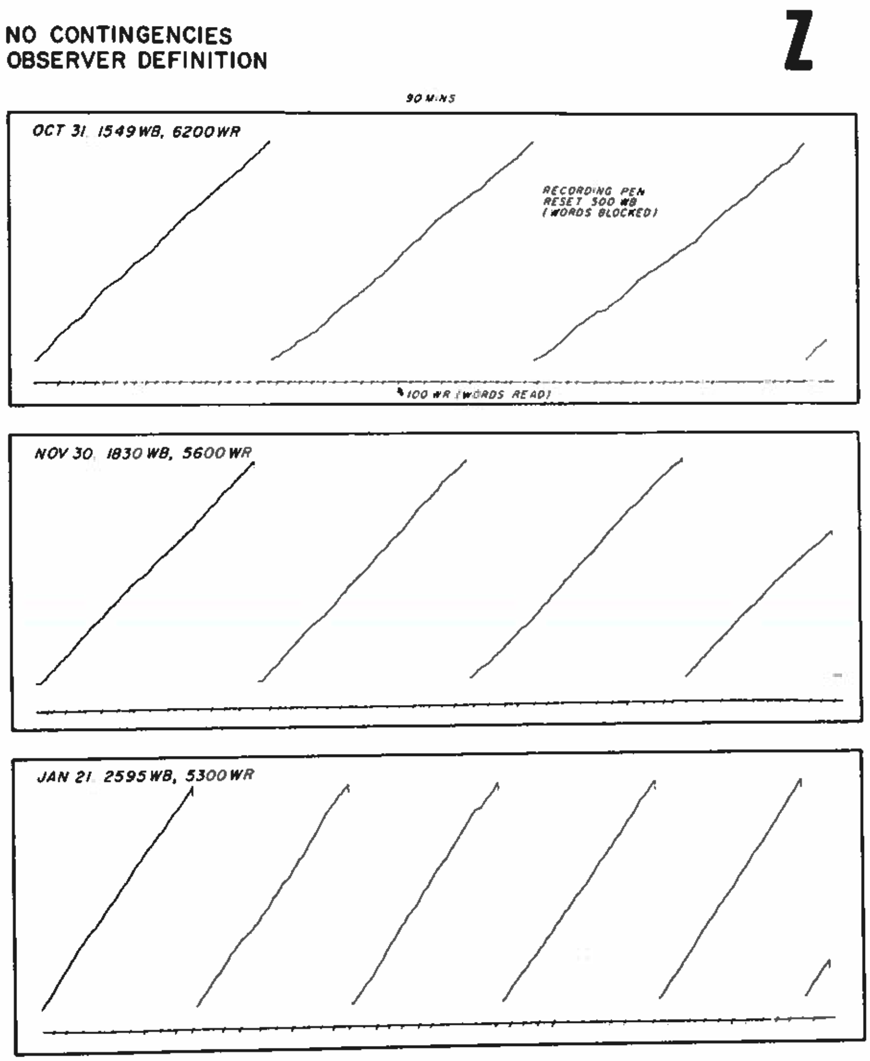

Fig. 2. The temporal course of development of blocked speech communication and reading rate for Subject Z. Note progressive increase in stuttering and decrease in reading rate.

server's responses were not under the contingency control of the subject's responses.

The remaining data are presented by subject.

Subject Z

The temporal course of development of blocked-speech communication for Subject Z is depicted in Fig. 2, which presents typical curves during his stabilization period. Between October 31 and January 21, blockage rate increased from approximately 1500 to 2500, when it stabilized. The accompanying reading rate decreased, from 6200 words read to 5300. Thus, stuttering nonfluencies can be considered as blocks to communication, since their prevalence decreases the amount that can be communicated.

Furthermore, *within* each session, stuttering diminished over time. On October 31, the first 500 responses required 25.8 minutes to occur; but at the end of the session, 30.7 minutes covered 500 responses. On January 21, the corresponding times are 16.8 and 16.4 minutes. The initial slope of each day is also the highest. These data are in accord with the adaptation effect reported in other studies (Naylor, 1953), where stuttering diminishes as a function of time. The *long-term* temporal development is unrelated, however, since nonfluencies *increased* over time.

Figure 3 shows the effects of making a 5-second period of delay contingent upon each blockage. It will be noted that monitor and subject display the same functional relations; hence, the changes represent blockages rather than control over subject's button presses. The data appear to answer the reliability question raised earlier. The effects of delay were specific to the class of responses upon which it was contingent, since reading rate *rose* as stuttering was attenuated, from approximately 5,000 words read to 10,000 words read. The adaptation effect of the preceding sessions was reversed: stuttering rate rose within each session. This was accompanied by a within-session decrease in reading rate, as the spacing between reading markers shows. On February 8, there was no delayed feedback. Response rate immediately returned to its original base level.

The effects of making presentation of delay contingent upon a blockage appear quite evident. Introduction of such

contingencies decreased stuttering rate, and their elimination returned it to its previous level. Similarly, reading rate was increased and then returned to its base level.

To ascertain if such introduction of delay would have long-term effects, the noncontingency sessions were continued. Figure 4 presents curves obtained during this second stabilization period. *Both* reading rate and stuttering rate declined. Possibly, the subject was merely reading less, the limiting case being no reading, no stuttering. Because the pay was the same whether reading was slow or rapid, absence of differential contingencies for such behaviors may account for the

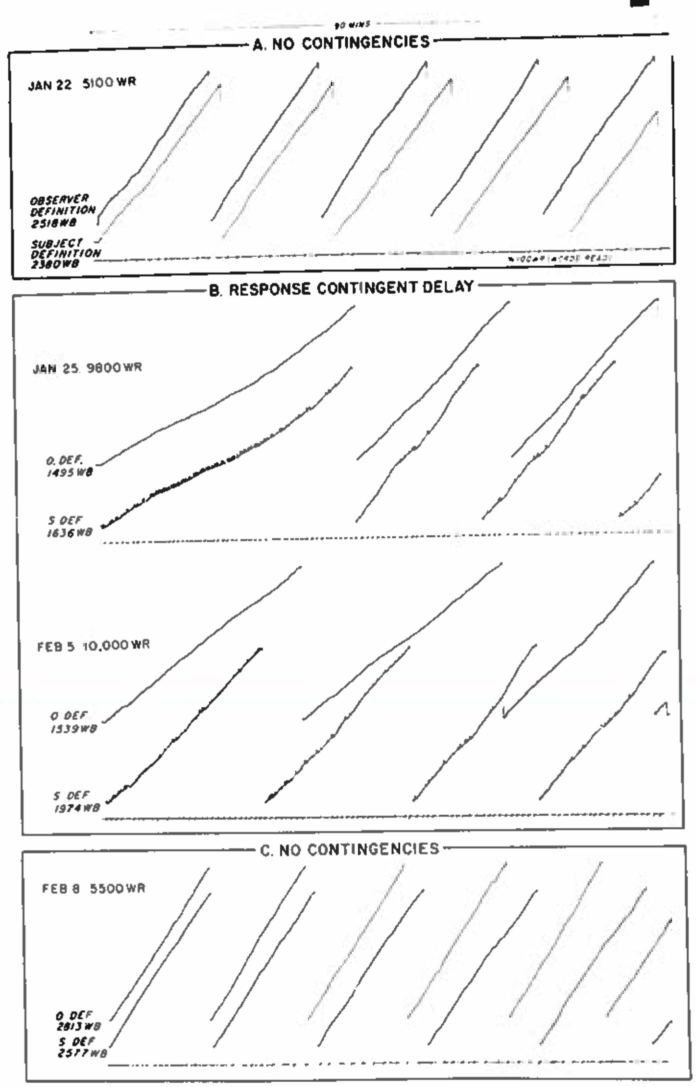

Fig. 3. Effects of making a 5-second period of 0.25-second delay contingent upon each blockage. A. Base-line performance. B. Introduction of blockage-contingent delay, first and last days. C. Reintroduction of base-line conditions.

deterioration in reading rate. The adaptation effect will be noted within sessions.

Figure 5 shows the effects of response-contingent delay, which was reintroduced on April 7. Stuttering rate dropped and continued to remain low during the next weeks, but attained some steady state. However, during this period of contingencies, reading rate rose from approximately 2,000 words read to 3,500. If decrease in reading rate is a function of absence of maintaining contingencies plus blockage that retard it, contingency-manipulated decrease of blockages may increase reading rate, thereby also increasing the blockages it carries. In all events, if words read per blockage defines reading efficiency, the results suggest that application of delay contingencies to blockages improves efficiency.

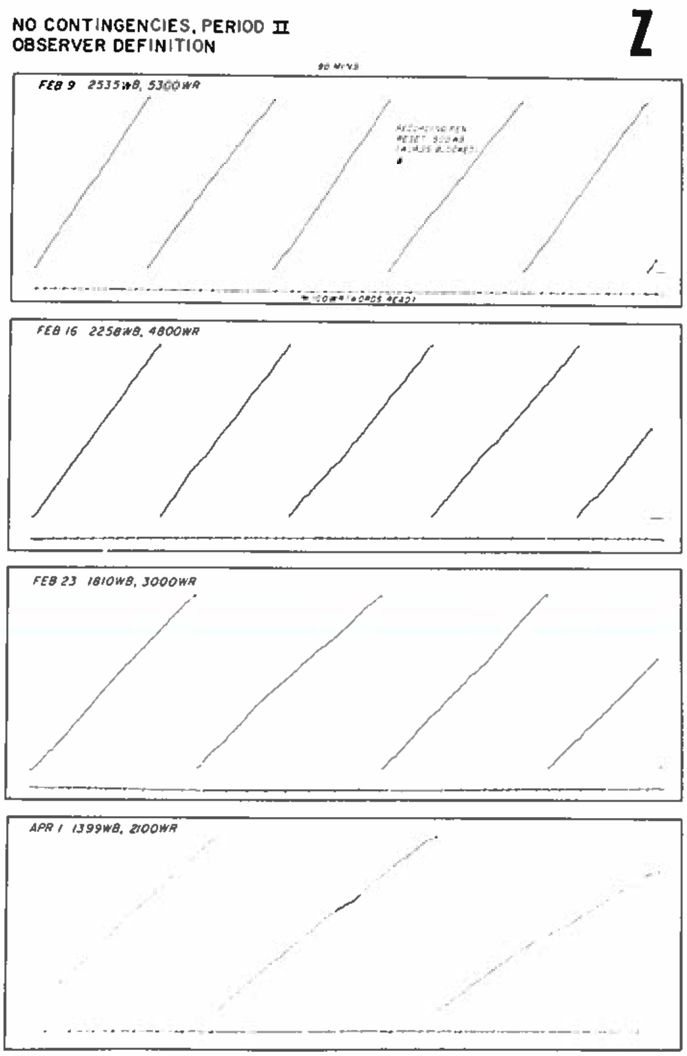

Fig. 4. Second base-line period; no contingencies applied. Note deterioration in reading rate.

Subject L

Figure 6 presents the temporal course of development for Subject L. For this subject, blockage rate diminished with time, whereas reading rate fluctuated. This subject's progress was marked by continual fluctuations, and the curves presented typify the trend. Within-session adaptation appears to be present.

On March 9, delay was presented continuously, that is, was constant and noncontingent upon any response classes. As Figure 7 shows, there were no marked effects upon rate of stuttering. Although reading rate was initially attenuated, with a drop from approximately 14,000 to 11,000 words read, recovery was complete on the next day.

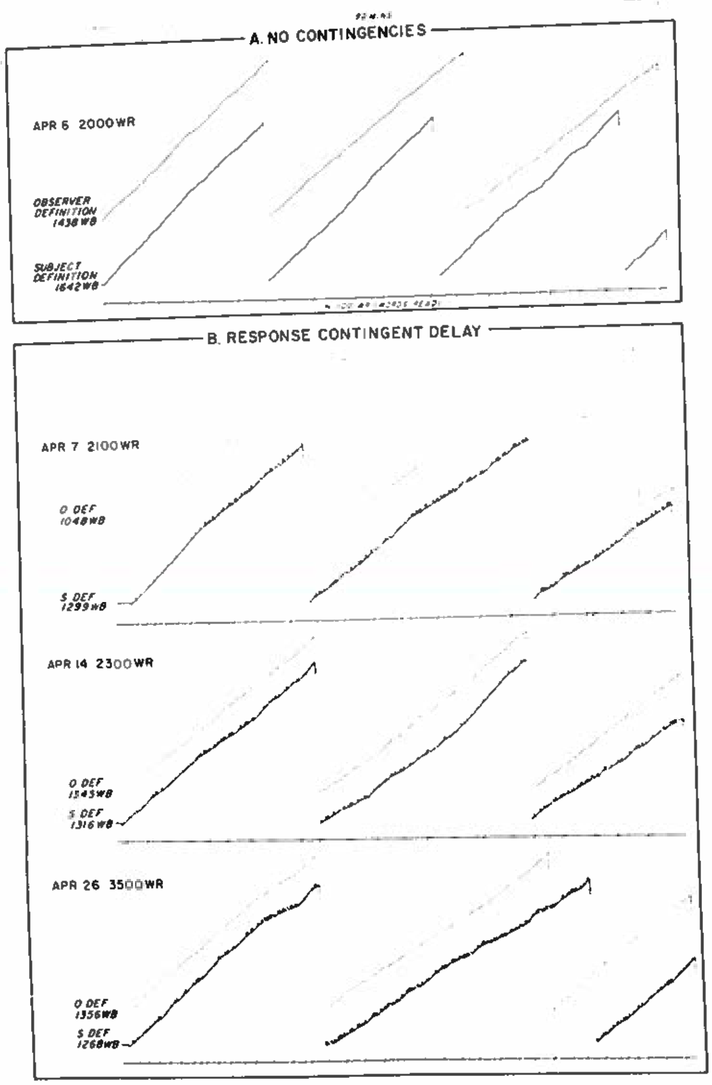

Fig. 5. Effects of reintroduction of stuttering-contingent delayed side-tone.

Figure 8 shows the effects of making delay *contingent* upon stuttering. This figure shows that nonfluencies dropped sharply, and then stabilized to a new low level. Reading rate tended to drop, too, possibly for the reasons given for Subject Z.

Subject S

Figure 9 shows the temporal development for Subject S. A steady state of blockage was reached early, whereas reading rate dropped. On February 9, delayed feedback was presented throughout the session, but each definition of stuttering *eliminated* the delay for 10 seconds. Initial sessions are presented in Fig. 10. This schedule is actually applying delay to flu-

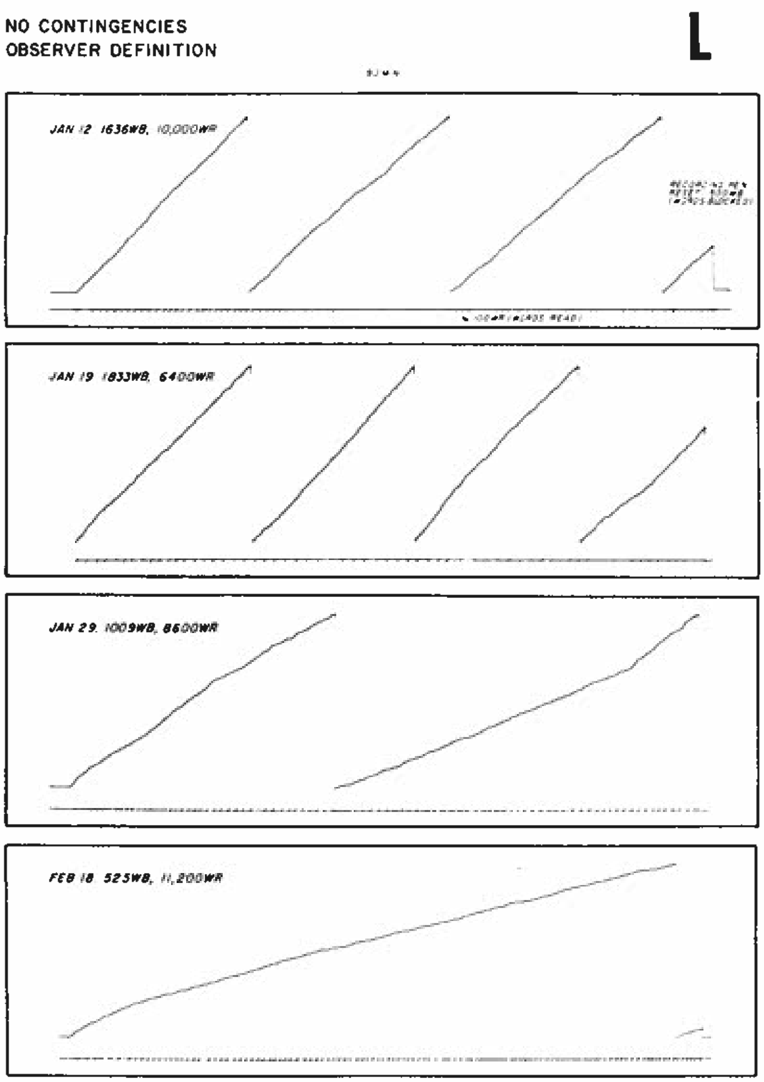

Fig. 6. The temporal course of development of blocked speech communication and reading rate for Subject L.

encies. Like the noncontingent delay for Subject L, reading dropped initially, from 3,300 to 2,500 words read; also, like this subject, recovery from such attenuation was complete during the following session. Also, if delay functions as an aversive stimulus, as was suggested by Subjects Z and L, making elimination contingent upon stuttering should *increase* stuttering.

On the first day, stuttering *dropped;* but on the second day, stuttering rose dramatically, almost doubling. These results would define delay as an aversive stimulus, increasing response rate during negative reinforcement, and decreasing it when its presentation is made contingent upon a response. Had the

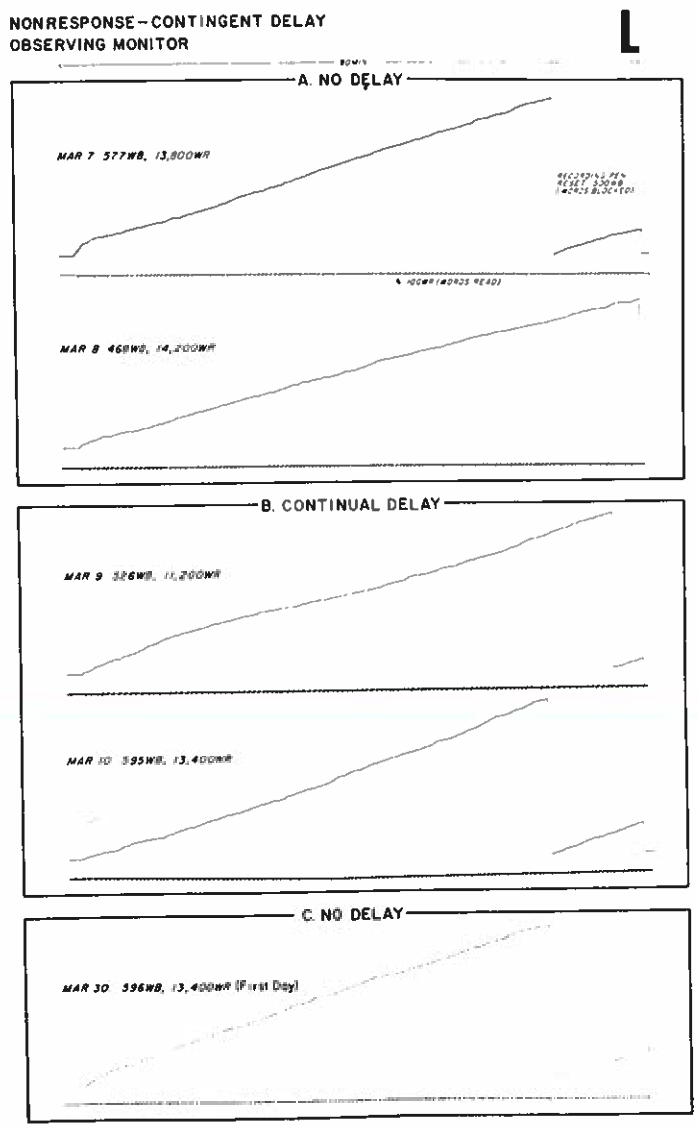

Fig. 7. Effects of continual delay (nonresponse-contingent) upon verbal behavior of Subject L. A. Operant level before delay. B. Delay. First two days. C. Return to normal side-tone.

experiment terminated here, this might have been the conclusion.

Further effects of this schedule are continued in Fig. 11, which depicts the emergence of a new response pattern. Two different patterns occur on February 11: a high rate of nonfluencies that serves to eliminate delay and restore normal side-tone, and a low or almost nonexistent rate of nonfluencies accompanied by continual delayed side-tone. These patterns were interspersed, with the slope of the former gradually decreasing, and duration of the latter increasing. On February 17, the subject recorded almost no stuttering, with the observer in close agreement. The relationship between reading rate

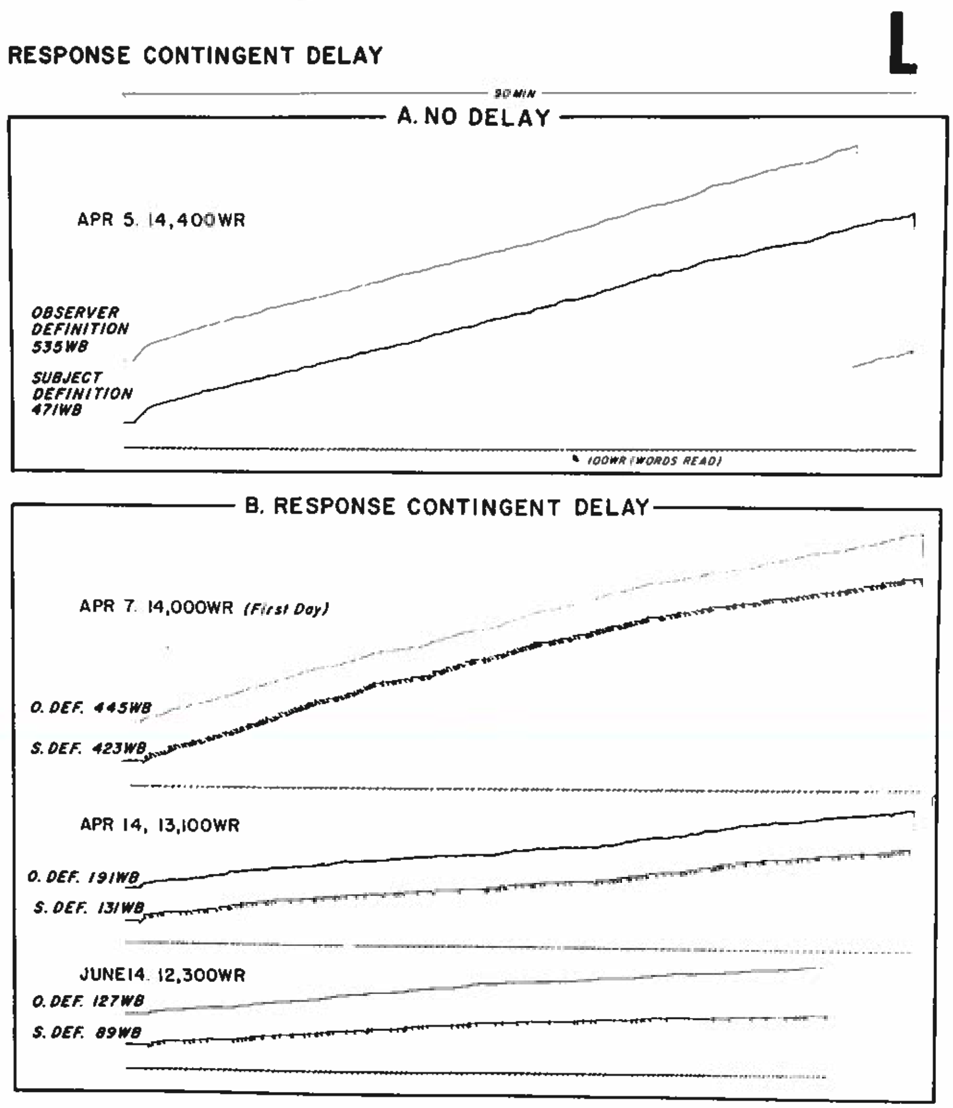

Fig. 8. Effects of making a 5-second period of 0.25-second delay contingent upon each blockage. A. Base-line performance. B. Behavior during response-contingent delay.

and stuttering appears most clearly on the record of February 23, where they are inversely related.

The almost day-by-day clinical-experimental progression is continued in Fig. 12. On February 24, stuttering is very low, and the subject is getting almost continual delay. Except for March 7 and 9, when there was a reversion to mixed patterns, the new pattern continued.

The new pattern involved stre-e-e-e-etchi-i-i-ing o-o-o-o-ut e-e-e-each glide or vowel so that about 12 words a minute were read; delivery was in a monotone. In case an equally bad pattern of speech had been substituted for the stuttering pattern, I attempted to alter this pattern by changing conditions and contingencies.

On April 4, normal side-tone was restored. As Fig. 13 shows, the new behavior persisted. On April 14, presentation of delay was made contingent upon stuttering. This *attenuated* stuttering for Subjects L and Z. Figure 14 indicates that it increased stuttering for Subject S, temporarily disrupting the new pattern, which returned the next day. Periods of response-contingent elimination were then alternated with periods of

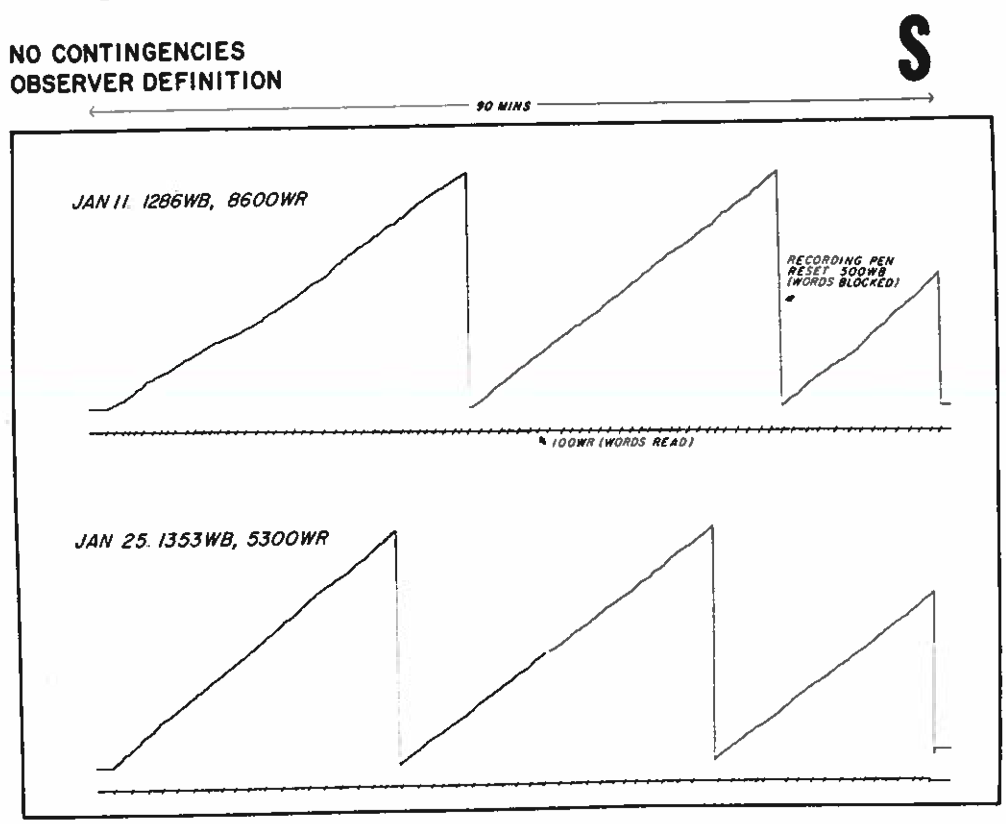

Fig. 9. The temporal course of development of blocked speech communication and reading rate for Subject S.

response-contingent presentation within the same session; but as Fig. 15 shows, the pattern persisted.

A series of 10-minute periods with differing schedules produced no change in response pattern.

I then decided to work with reading rate directly. The average number of pages was counted and tripled; and Subject S was told that he would get the same pay as before, but could leave when he was through reading (the tripled task). In Fig. 16, the May 31 curve is the prolonged pattern under interspersed conditions. On June 2, speed-up was introduced. The subject tripled the number of pages read and did so in one-third the time! Because three such days represent about the length of a regular 90-minute session, three-session periods are totalled at the right. These figures can be compared with

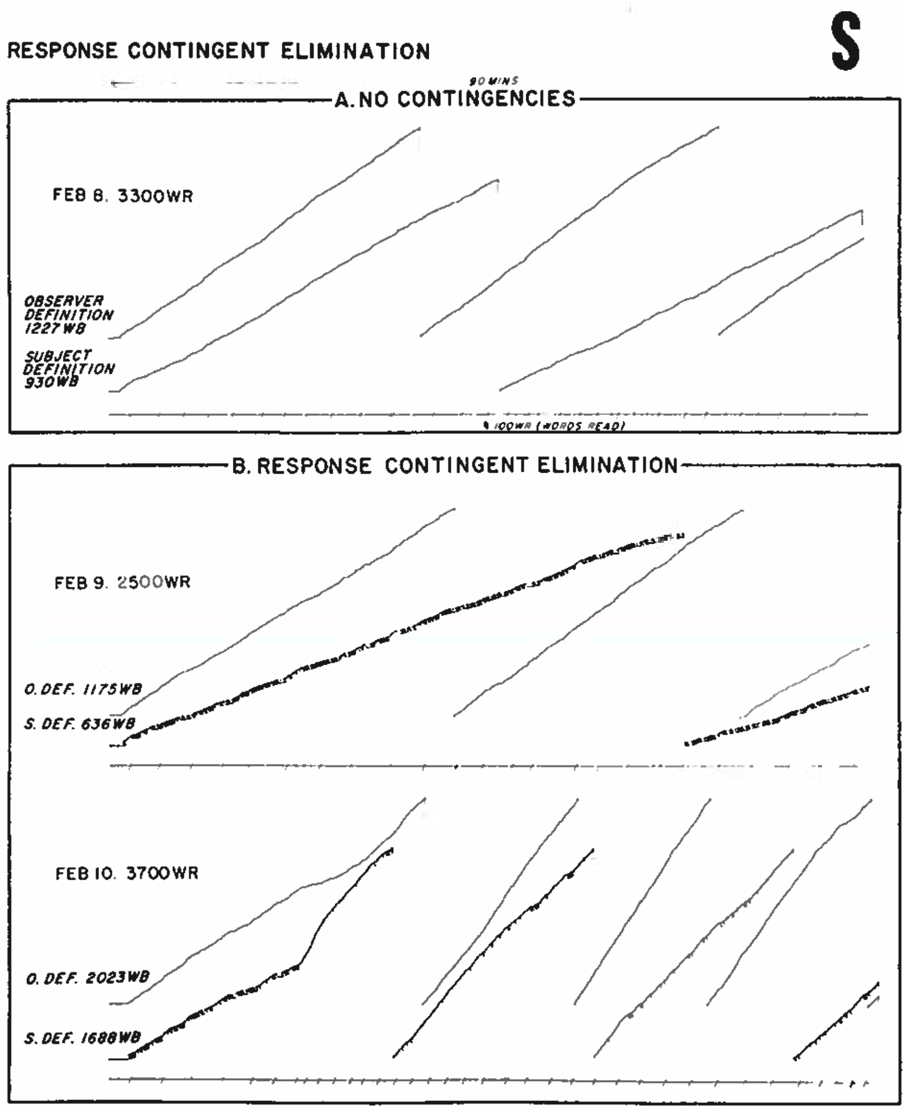

Fig. 10. Effects of 10-second elimination of constant delay by stuttering. A. Operant level. B. Sessions of response-contingent elimination. First two days.

the *original* steady-state performance of the subject, presented at the bottom. His reading is now approximately 11,000 words (for 90 minutes), compared with the 4,400 base line; stuttering is now 300-400 words blocked, compared with 1,000 base line, or at least sevenfold increase in efficiency.

Subject K

The temporal development for Subject K is presented in Fig. 17. Blockage rate rose and reading rate declined, with patterns similar to those of Subject Z.

Delay made contingent upon stuttering was introduced between January 25 and February 10. Figure 18 shows the

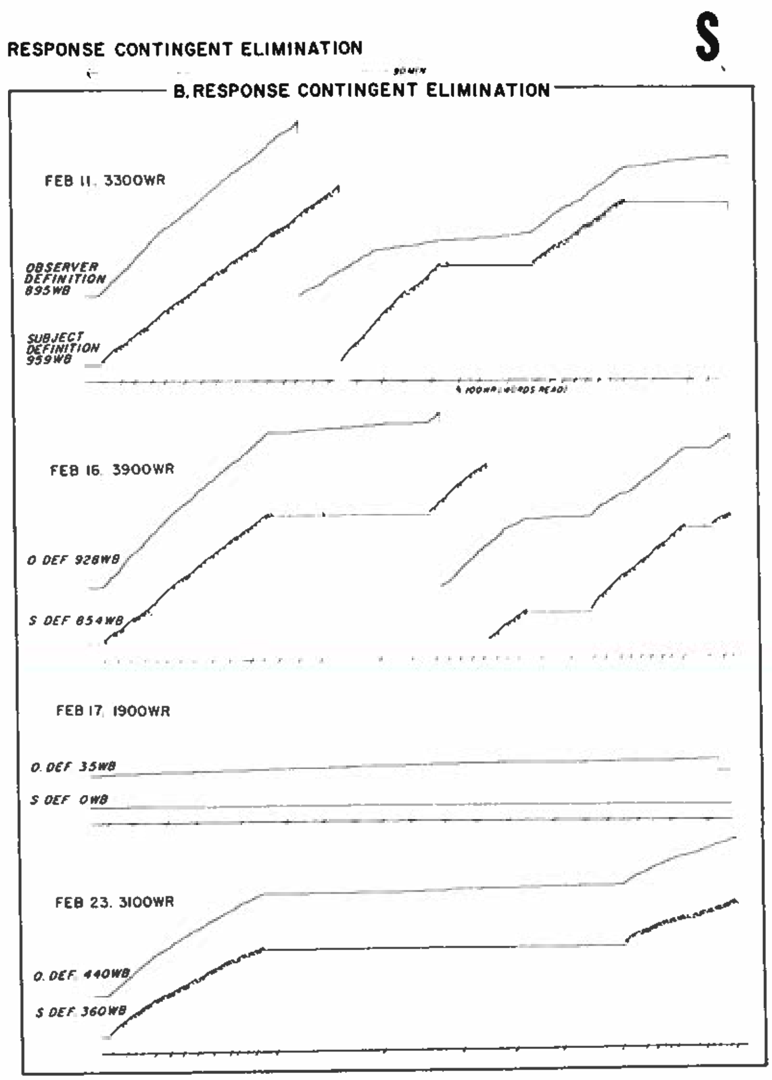

Fig. 11. Further effects of stuttering-contingent elimination of delay. Note decrease in slope and increase in periods of no stuttering, with prolongation of each word read.

sharp attenuation of stuttering; the high reading rate was not affected. On February 10, normal noncontingent side-tone was reintroduced and the attenuation persisted, rising gradually in trend. By March 10, it was approximately two-thirds of the original October 28 session.

On April 7, elimination of constantly present delay was made contingent upon stuttering. Figure 19 shows the effects. Initial presentation of delay during fluency lowered the reading rate, as it did for other subjects; rate of stuttering was initially not affected. Thereafter, stuttering began to diminish, coming down to 50 words blocked on May 12. As with Subject S, delayed side-tone was not being eliminated by the subject's behavior.

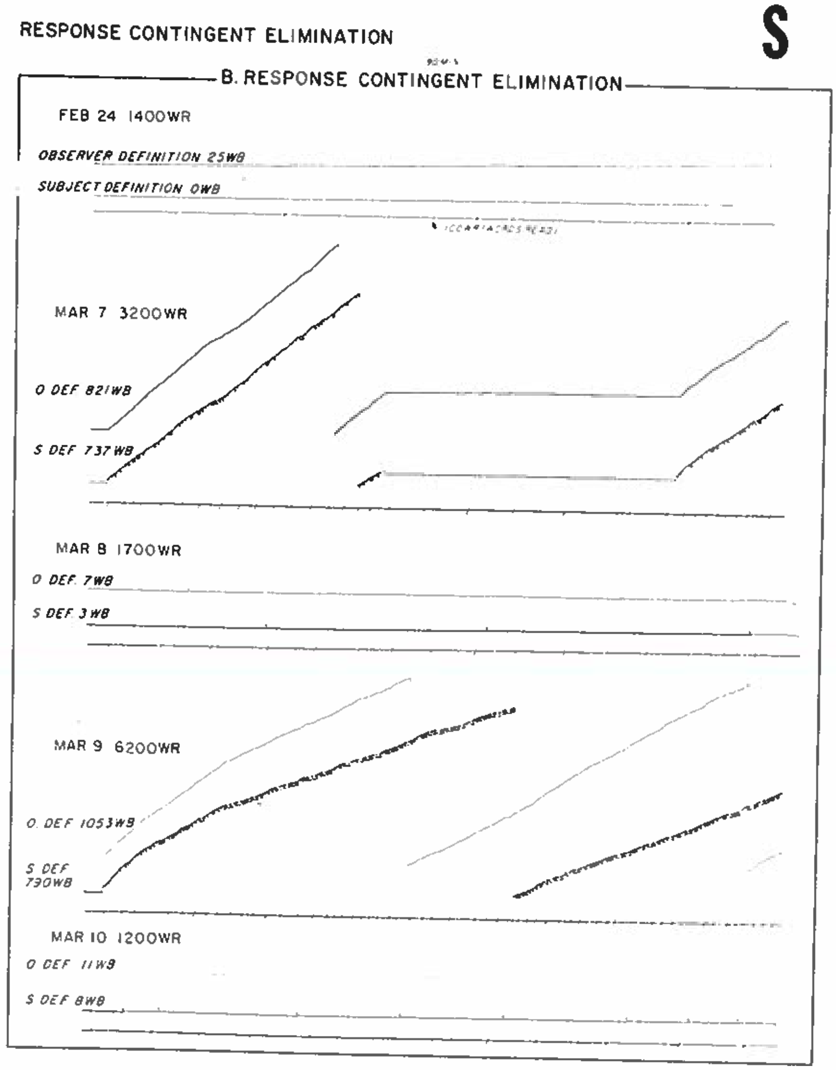

Fig. 12. Emergency of stable nonstuttering pattern under elimination contingency. Note low stuttering and reading rates of March 8 and 10.

Figure 20 presents summary data for this subject and a follow-up curve. Section A depicts a typical steady-state curve during stabilization, and Section B, the attenuation in stuttering produced by having a fixed period of delayed side-tone contingent upon stuttering. Section C depicts the effects of making elimination of delay contingent upon blockages. Initially, both reading rate and stuttering are attenuated; blockage reached its lowest level, with reading rate showing recovery. This range of blockages is well within the usual range. (See next section.) This subject was terminated on June 15. On July 27, about 1.5 months later, he was recalled. Section D indicates that the patterns produced during the elimination period continued without change over this course of time, into conditions involving ordinary side-tone.

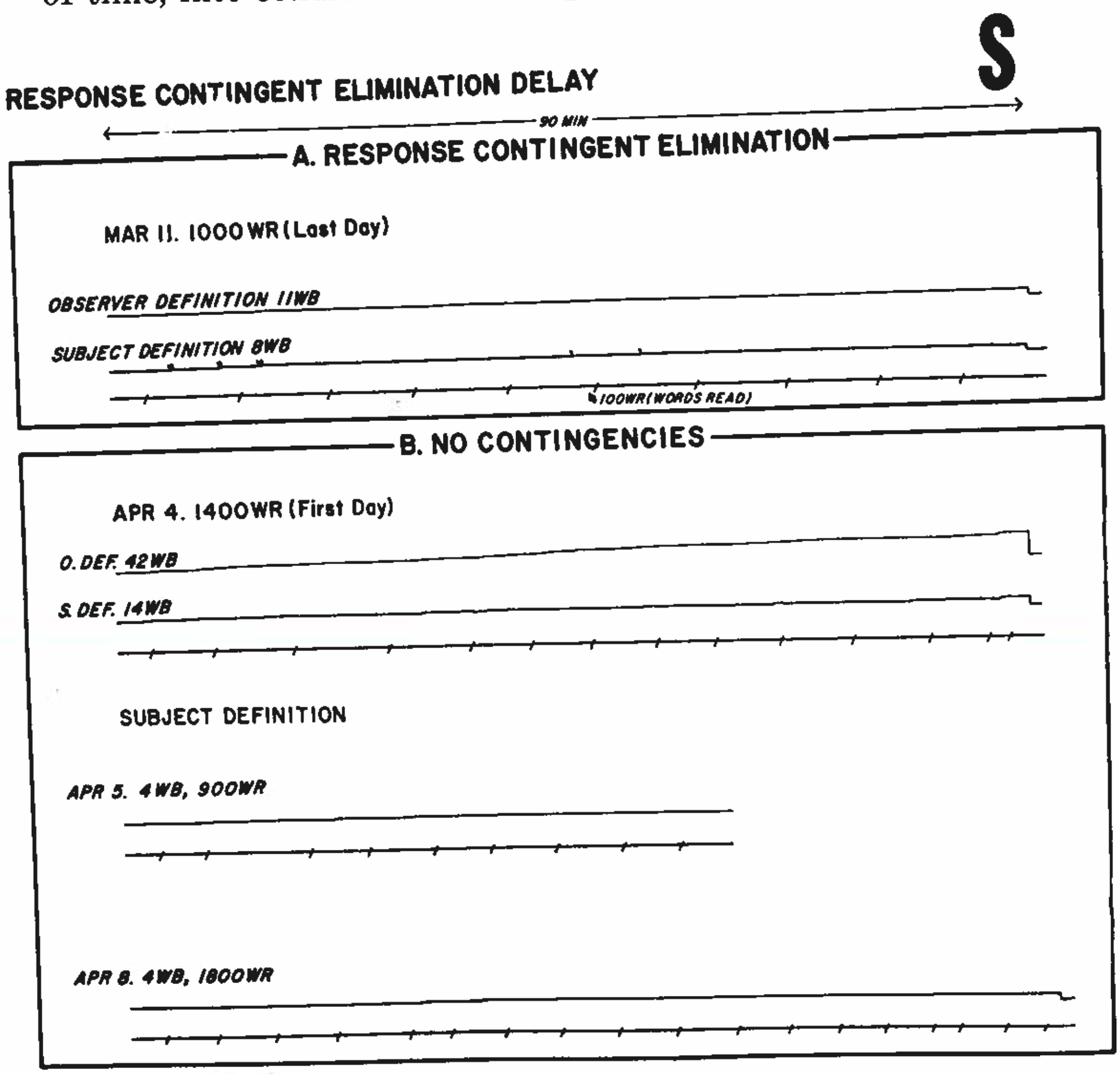

Fig. 13. Persistence of new pattern beyond original instating conditions. A. Instating conditions (elimination schedule). B. Elimination of schedule and return to normal side-tone.

NORMALLY FLUENT SUBJECTS

Attempts to shape fluencies and nonfluencies using delayed side-tone as a contingency were not successful with normal subjects. Figure 21 shows that delayed side-tone could shape other behaviors. In this figure, the periods are constant (noncontingent) delay, delay contingent upon blockage, and constant delay. Words read increased when constant delay was eliminated, and dropped when it was reinstituted. From the subject's record, the delay also eliminated the nonfluencies that produced it during the contingency period. However, the *observer* record indicates no such functional relation, indicating that the delayed side-tone gained control over the button-pressing response that produced the contingency.

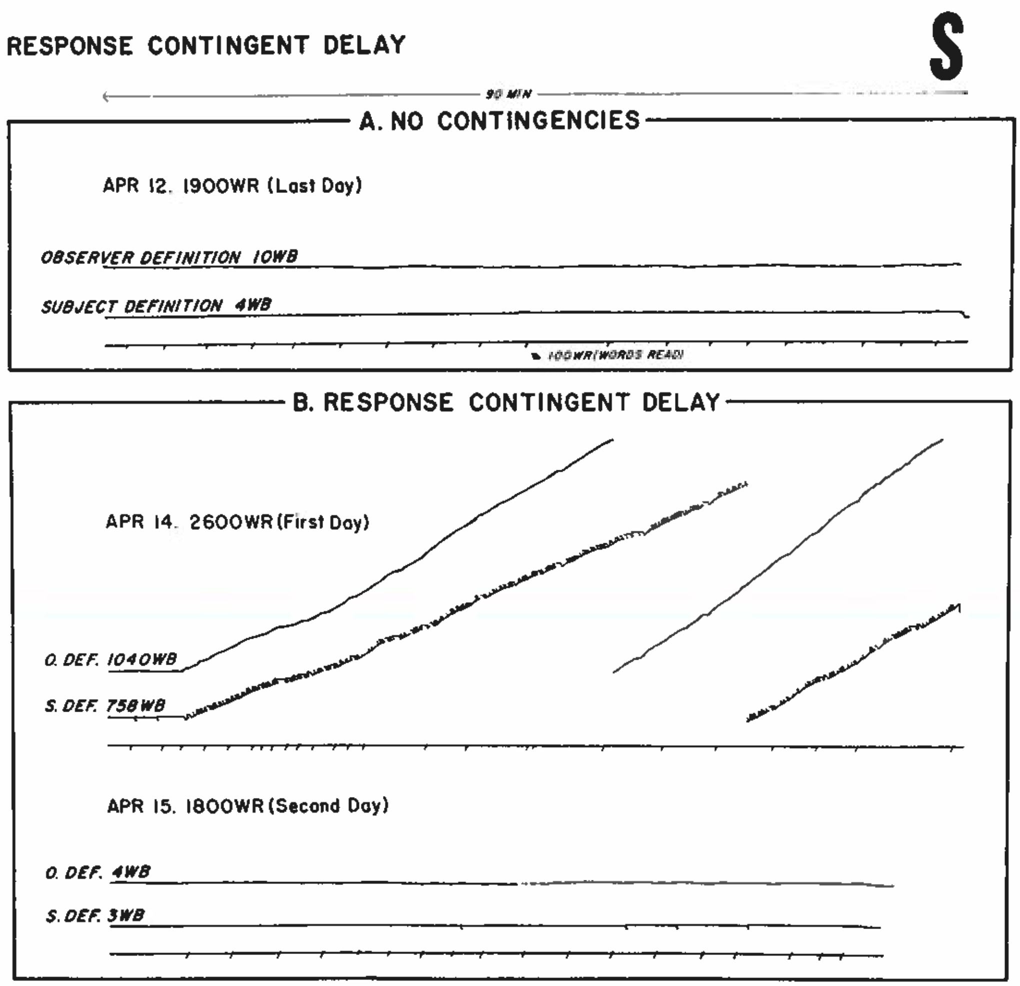

Fig. 14. Effects of making presentation of delay contingent upon stuttering. A. New base-line performance. B. Introduction of contingency. Note response-pattern deterioration during first day, followed by recovery thereafter.

The extremely low blockage rate of normal subjects made it difficult to shape such behavior. Figure 22 depicts typical curves of a subject with such a low rate, which decreased over time. Another difficulty with these subjects was that the effects of delayed side-tone tended to be transitory. Figure 23 presents curves from two subjects. For N3, introduction of constant delay immediately lowered words read from 16,000 to 15,700, an effect noted with the stuttering subjects. In contrast to these subjects, rate of blockage increased for normally fluent subjects. No delay the following day (July 7) produced an increase in words read and decreased in blockages. Reintroduction of delay the day after was accompanied by *increase* in reading rate, which continued at a new high thereafter. Block-

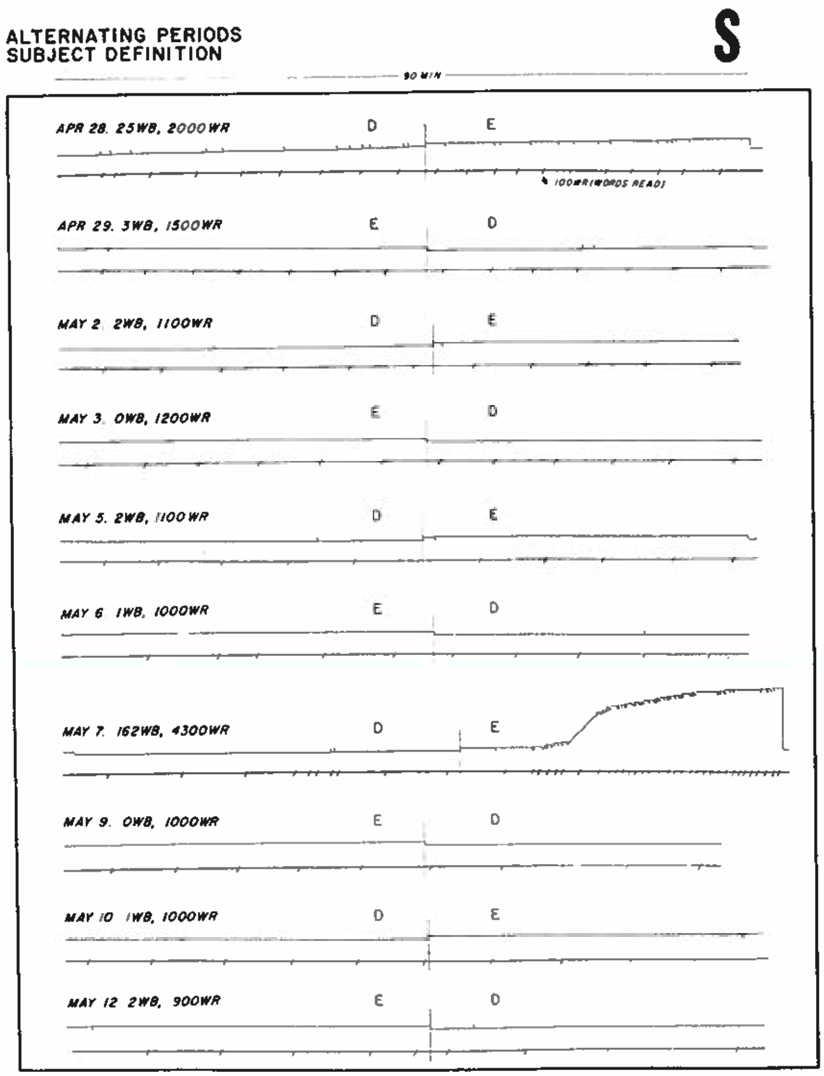

Fig. 15. Persistence of pattern under varying conditions. C. Response-contingent elimination. D. Response-contingent presentation of delay.

ages dropped, and both blockages and reading rate stabilized into patterns affected neither by delay side-tone nor normal side-tone. The record of N7 depicts identical effects.

Experimental Analysis of Delay

These transitory effects of noncontingent delay, noted in both stutterers and normally fluent subjects, suggested another analysis of its role in verbal behavior.

It was noted that the initial effects of delayed feedback, when accompanied by nonfluencies, were to depress reading rate. Thereafter, there was recovery, with recovered rate often

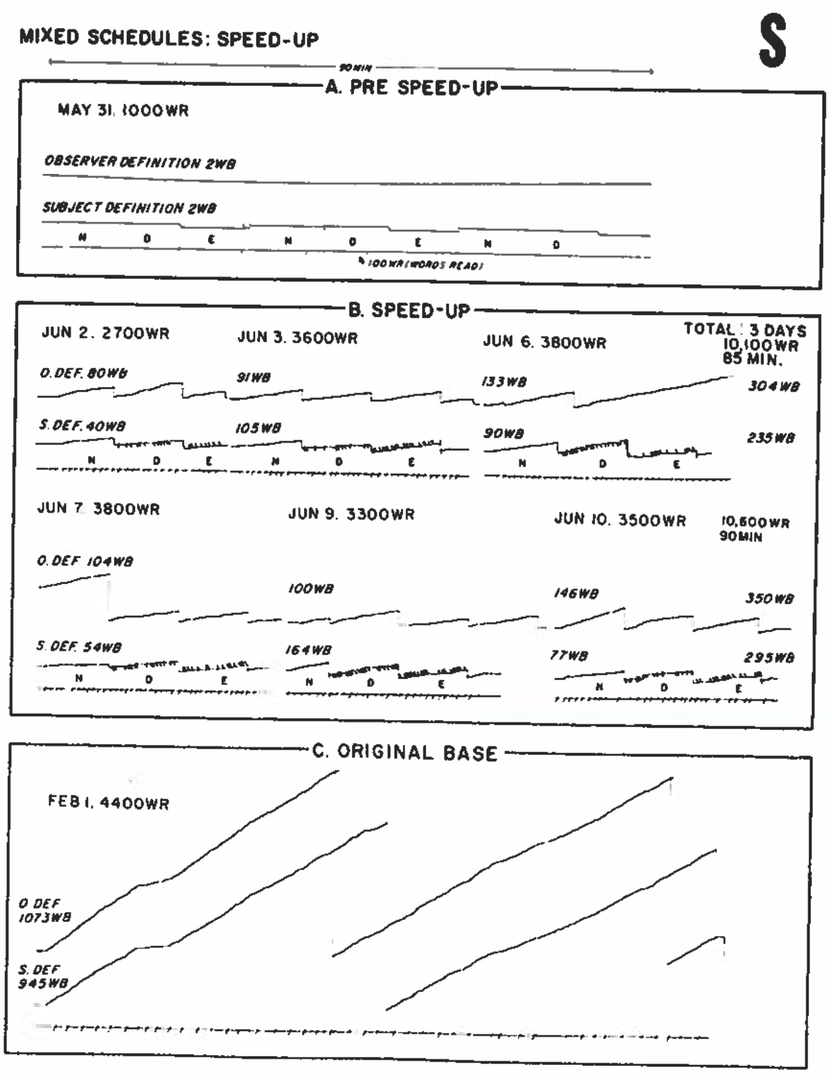

Fig. 16. Effects of applying contingencies to reading rate. A. Performance under mixed patterns. Note low reading rate. B. Speed-up period. Subject released when three times number of pages read before is completed, but paid for full session. C. Original base-line performance.

high. Where such pairing of delay and fluency was part of the elimination schedule, Subject S prolonged his vocalization.

Conditioned responses can be demonstrated to be quite specific to the conditions under which they have been established. A change in these conditions, such as the presentation of ambient noise, or, for that matter, turning down the ambient noise level present throughout a conditioning session (Azrin, 1960) can disrupt the behavior. One of the conditions under which verbal behavior is established is the immediate presentation to the speaker of the sound of his own voice. Delay disrupts this temporal relation. Speakers to whom delay is presented for the first time exhibit nonfluencies and drastic changes in verbal behavior. They may throw off the earphones and stop talking. The verbal behavior of subjects in the present

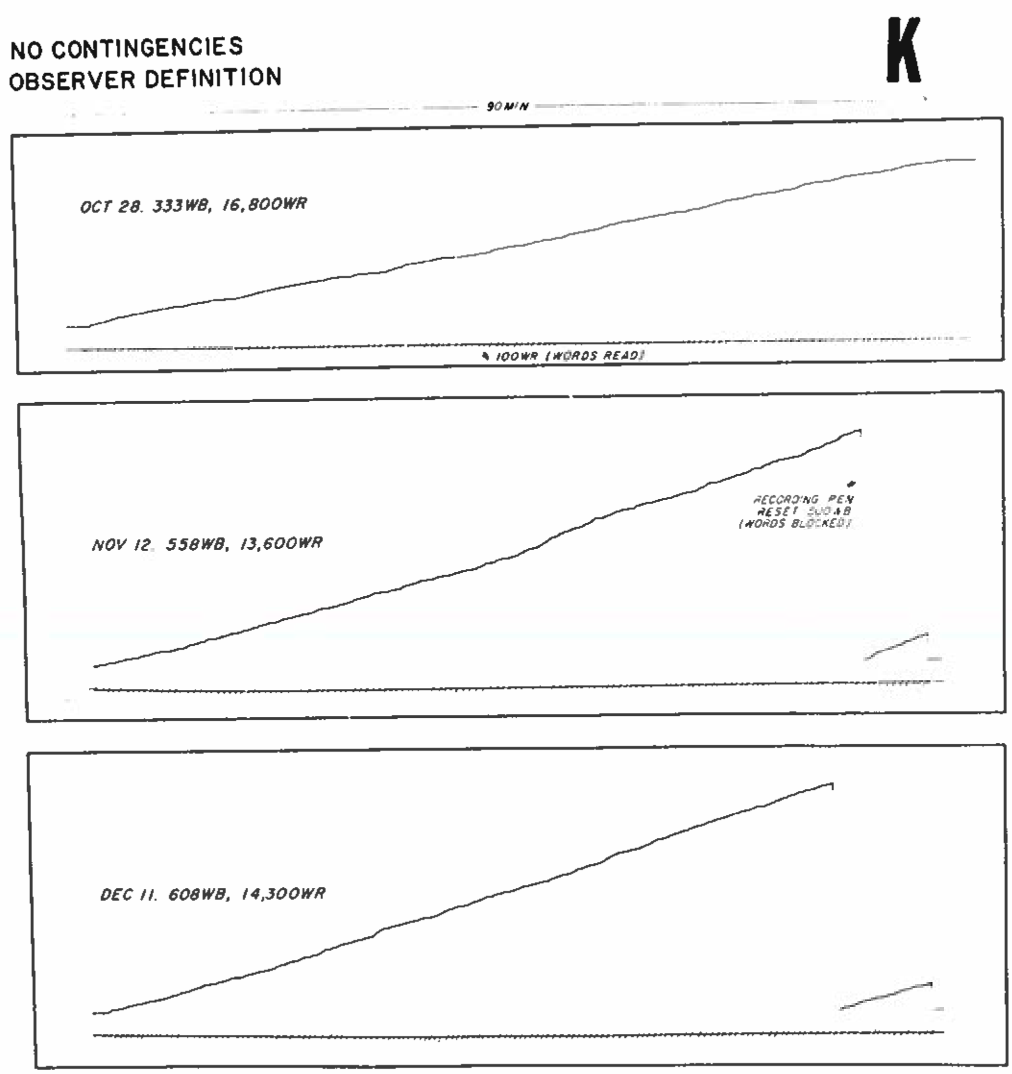

Fig. 17. The temporal development of blocked speech communication and reading rate for Subject K.

situation was under the strong control of monetary reinforcement, which was contingent upon continuation of verbal behavior. *If verbal behavior is to continue, the conditions under which it was established must be reinstated.* One way of such reinstatement is through prolongation of phonations, as Fig. 24 suggests. The first pairing of response and stimulus produced involves temporal congruence of the two, under normal conditions. The second pairing in the illustration is that of initial delay, and there is no congruence. This is a change in the normal stimulus conditions, and the result is disruption of behavior. In the third pairing presented, the subject reinstates the temporal congruences of the first case (normal speech conditions) by prolonging his phonations, except for

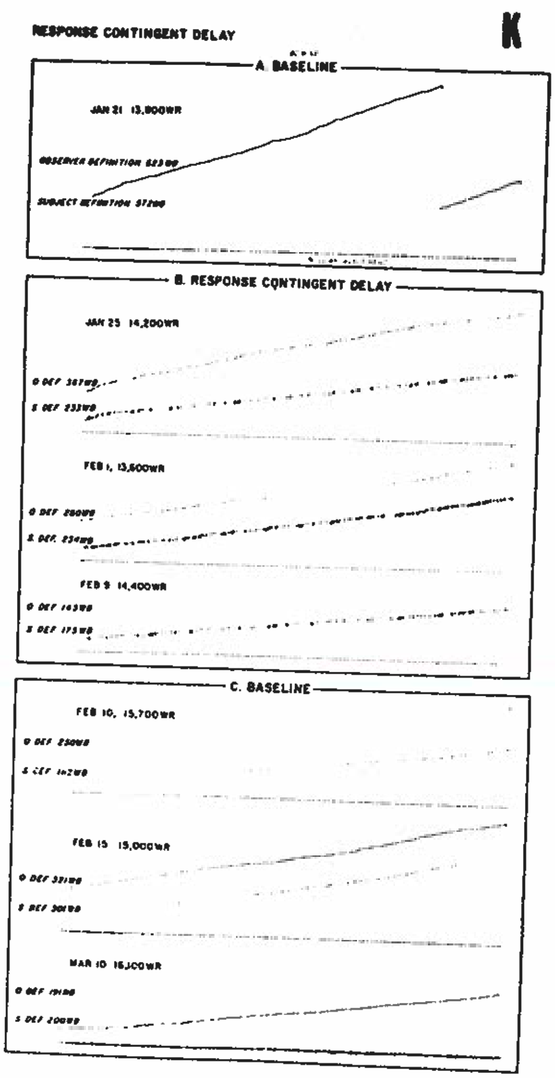

Fig. 18. Effects of making a 5-second period of 0.25-second delay contingent upon each blockage. A. Base line. B. Contingency period. C. Normal side-tone reinstated.

beginnings and ends of syllables. The greater the prolongation of medial sections, the greater the clipping of beginning-terminal sections, the greater the return to the stimuli in whose presence speech has been established.

However, the conditions of establishment of speech can be reproduced at least one other way. This involves having the behavior come under the control of conditions that have not been changed by the delay. Bone conduction is unaffected, and stimuli generated by lip movements may also be unaffected. By lowering one's voice, the ratio between the novel stimulus input and the unchanged inputs from bone and lips is decreased. Stated intuitively, the subject can thereby decrease his listening to himself, either by speaking more softly, or by other means.

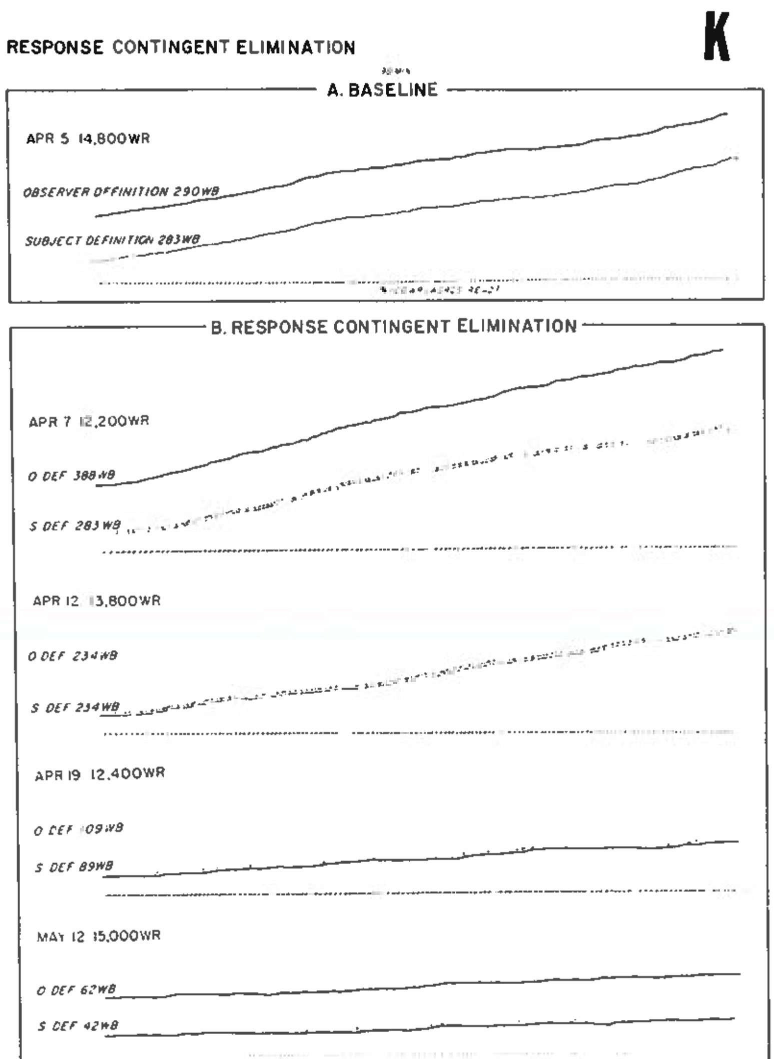

Fig. 19. Effects of 10-second elimination of constant delay by stuttering. A. Normal side-tone. B. Elimination conditions.

To investigate this possibility (Goldiamond, Atkinson, & Bilger, 1962), normally fluent subjects who had stabilized under continual delay to read fluently were run. The conditions were the same as those discussed, except that an Echo-Vox Senior, matched to produce the same volume as the Ampex previously used, was introduced for the delay. Delay can be varied with this apparatus. Before each 10-minute period that was run, the experimenter instructed the subject to *listen* or not to *listen* to his own voice as he read. Delays of 0.00 (no delay, Ampex used), 0.20, 0.30, 0.40 second were used.

Blockages were *not* recorded. Instead, the cumulative records depict *reading rate*. At every 10 words read, the monitor pressed a microswitch that recorded on the cumulative pen

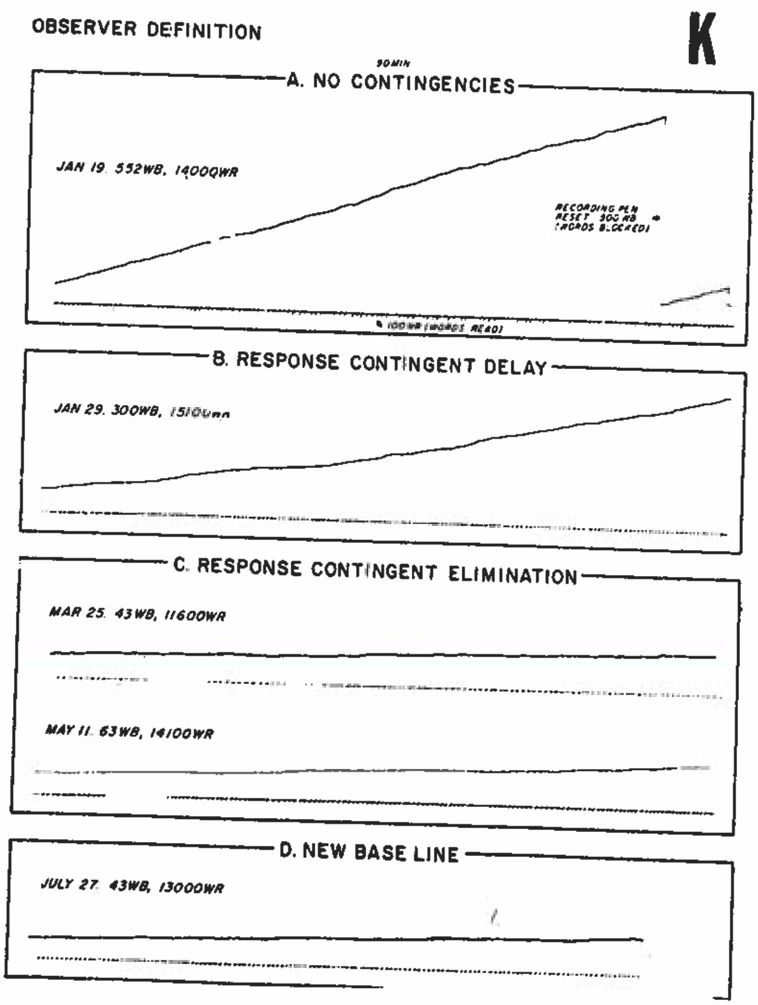

Fig. 20. Summary, Subject K. A. Base Line. B. Typical curve after making presentation of delay contingent upon blockage. C. Curves after making elimination of delay contingent upon blockage. D. Recheck 6 weeks after termination of experiment. Note apparent permanence of attenuation of stuttering.

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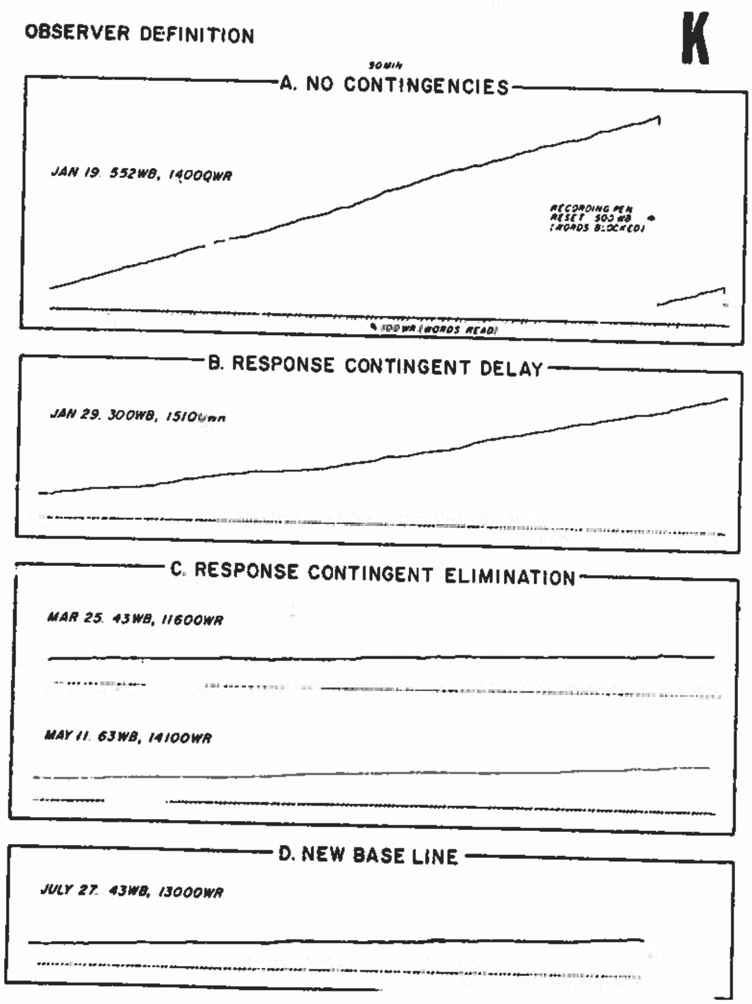

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and on digital counters. Both were reset after each period. Because the period was 10 minutes, and the units were of 10 words, each entry represents average reading rate in words per minute. The instructions follow:

"As you know, this is an Air Force project. The Air Force is vitally interested in communication between airships, and the room you are in is designed to resemble the control rooms used in communication. Undoubtedly, you have seen movies or television shows of people on the Moon trying to communicate with Earth. Each sound takes a long time before it gets back. Now, on some space ships, there will be the same problem. Since the space ship is shorter than the distance between the Moon and Earth, the delay will be shorter; it will be approximately the length you have been getting in your earphones. The Air Force is interested in communication under those conditions, and this is why you have been getting all

N3

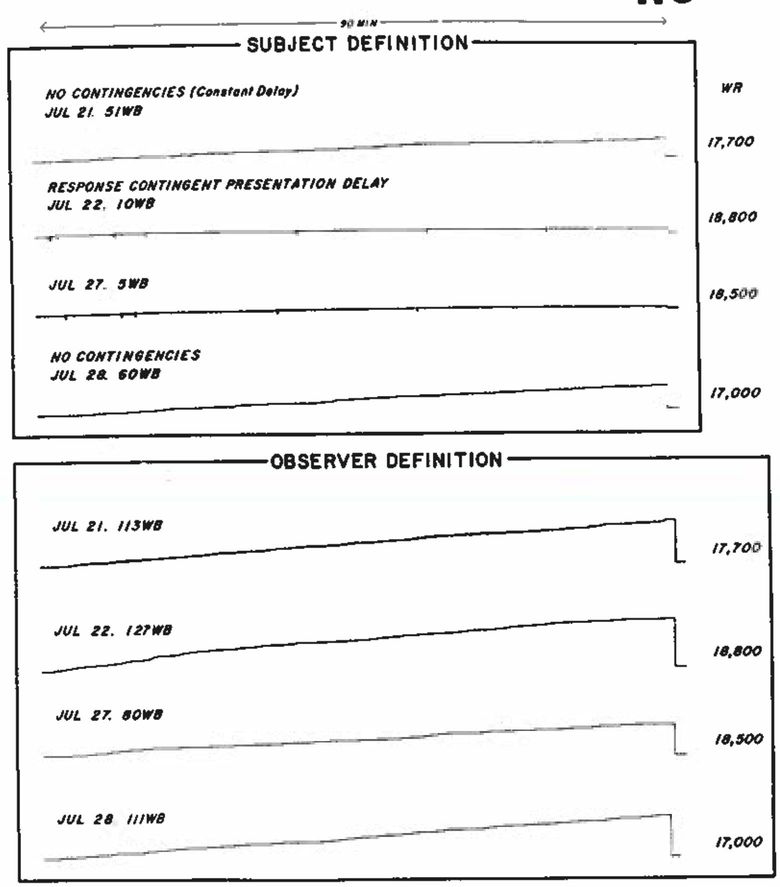

Fig. 21. Effects of responses of normally fluent subject after making a period of delay contingent upon blockage. Discrepancies between observer and subject indicated that button presses were controlled rather than nonfluency.

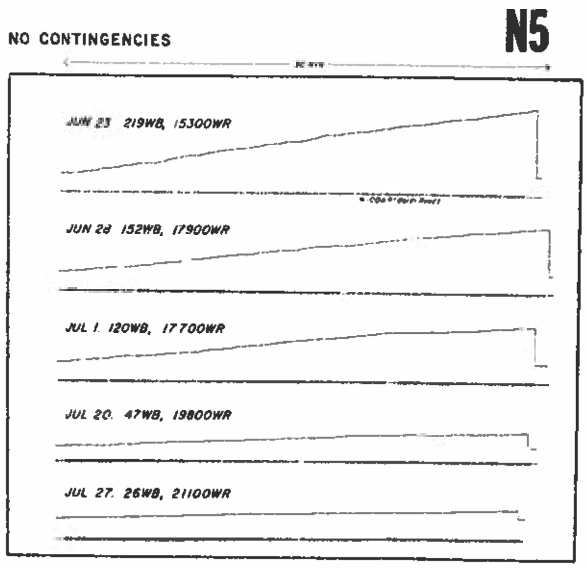

Fig. 22. The temporal development of blocked speech communication and reading rate in a normally fluent subject.

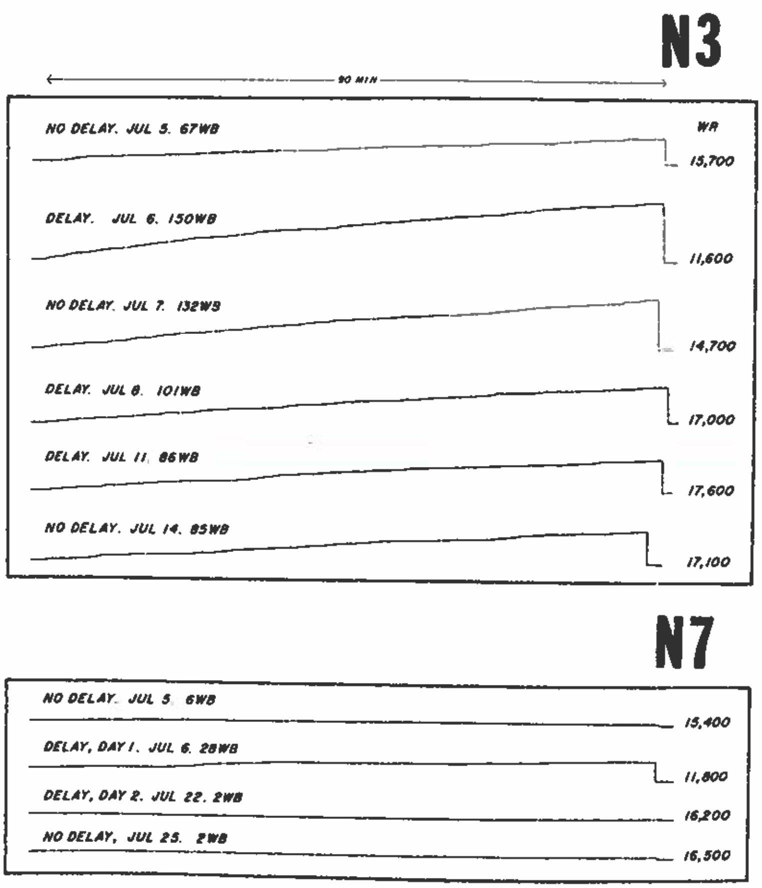

Fig. 23. Transitory effects of noncontingent delay upon two normally fluent subjects.

that delay. I will come down at intervals and tell you what to do.

"For the next period. I want you to read as rapidly and in the same manner as before, *and also* (or *but*) I want you *not to listen* to yourself as you read."

This type of instruction will be referred to as *nonlistening* instructions (abbreviated as *N)*. Another type of instruction given will be referred to as *listening* instructions (represented by *L)*. The statement here was: "For the next period, I want you to read as rapidly and in the same manner as you did before, *but I also* (or *and I also)* want you to *listen to yourself* as you read."

The *but* and *also* in brackets refer to substitutions made for the preceding italicized words when the instructions for one period differed from, or were identical to, the instructions of the preceding period. Each session was begun and terminated by a loud auditory signal.

If the delay periods are divided into delay and no delay, and L and N instructions, it will be observed that this is a

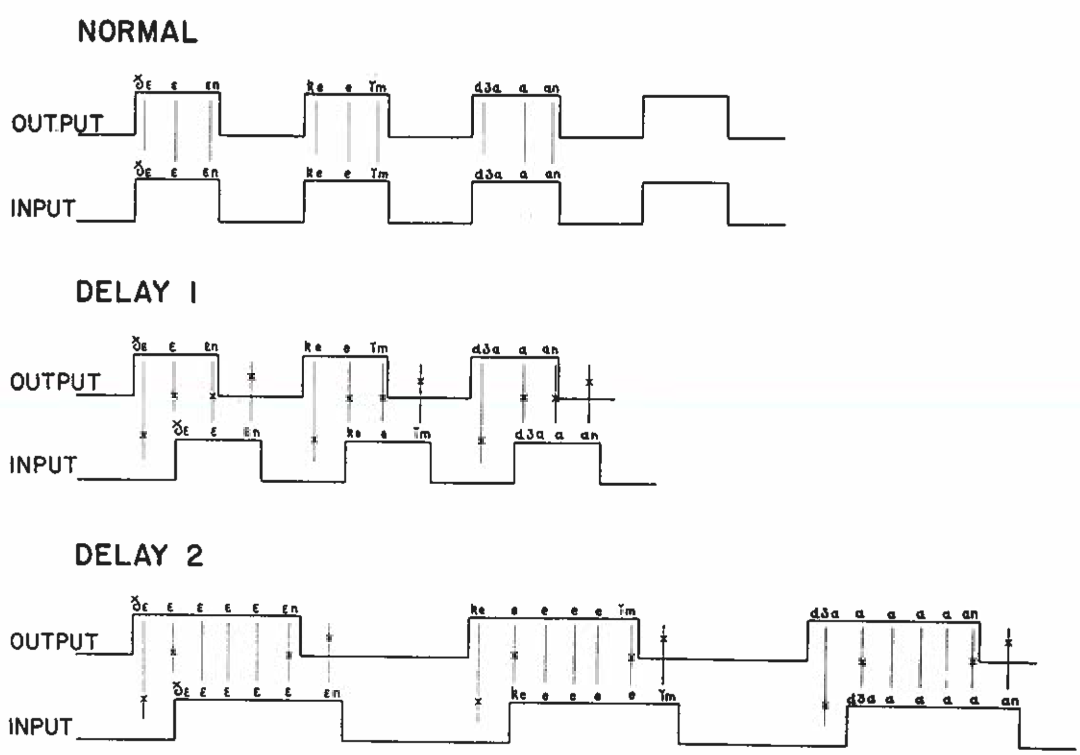

Fig. 24. Reinstatement of conditions under which verbal behavior was established by prolongation. Normal response (output)—stimulus (input) relations, compared with relations under initial introduction of delayed input. Note return to normal relations under later conditions.

factorial design. If reinstatement of previous conditions is involved in return to previous rates, the following should hold: where there is *no delay*, instructions *L* or *N* should have little differences, because the stimuli in whose presence verbal behavior has been established have not been changed. Where there is *delay*, *N* instructions should facilitate control by the unchanged nonauditory stimuli, and disruption should be minimized (in subjects who have overcome it). Where there is *delay L* instructions should facilitate control by the auditory stimuli that are novel, and there should be disruption.

Results

Figure 25 presents the results for two subjects. On August 20, Subject B made at least two ranges of response: 171-196 under Delay-L conditions, and 217-261 under the other three. The drop in rate under normal side-tone-L conditions may be in a third range, thus, the ranges are 171-196, Delay-L; 217, Normal side-tone-L; and 224-261, Delay-N and Normal-N. The highest rate (260 wpm) was obtained under a delay condition.

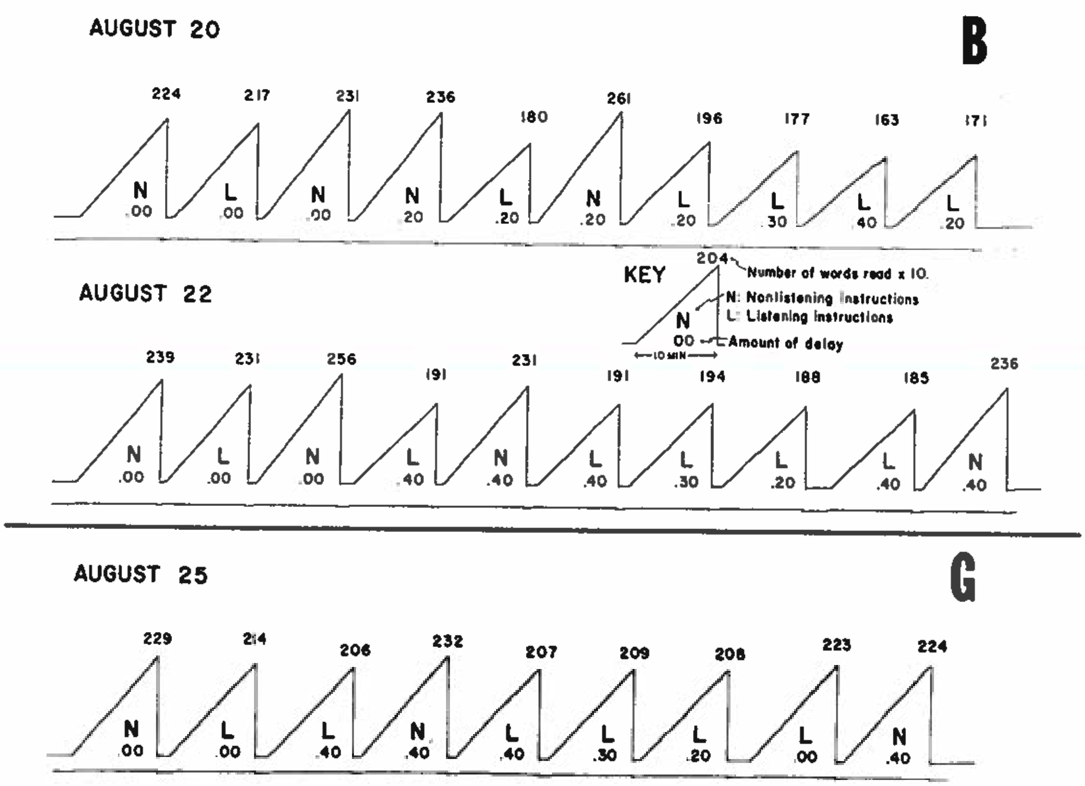

Fig. 25. Effects of instructions to listen (L) and not to listen (N) upon reading rate under varying conditions of delayed feedback.

The same subject was rerun on August 22. Again, there is a decrement under normal side-tone-L; but the response rate of 231 wpm is the same as the 231 wpm of N.40 and is, accordingly, within its range. The two ranges are then 185-191 for Delay-L and 231-256 for the other three conditions. The narrowness of the former range should be noted. The Delay-L conditions were at the end of the session. To find out whether or not the decline was temporally related, a condition producing a higher rate, N.40, was reinstated. The resultant 236 wpm rate is remarkably similar to the 231 rate obtained for the preceding N.40.

Subject G was run on August 25. The ranges appear clearly as 206-209 for Delay-L and 214-232 for the other three. Again, there is attenuation in the second condition: but repetition of that condition at the *end* of the session produced a response rate characteristic of the three-condition group.

These results suggest that one response mechanism for returning verbal behavior to the control of stimuli in whose presence it has been established, when novel stimulus conditions replace the established conditions, is to bring the behavior under the control of those conditions that have not been changed.

The absence of a functional relation between amount of delay and reading rate may be related to shortcomings inherent in instructions of the type "listen" and "don't listen." Attempts were made to introduce differential auditory control over the response without such instructions, but these were not successful in establishing a functional relation. This is the subject of current research.

Discussion

The data presented suggest that like other conditioned behaviors, the same stimuli must be present to maintain verbal behavior as were present when it was established. The stimuli specifically investigated in the experiments reported were the auditory ones that the subject produces through his verbal responses. These stimuli are both contingent upon the verbal response, that is, will not be presented unless the response occurs, and also precede the next response. In this respect, they are similar to the stimuli of chaining experiments, where

a response produces a stimulus that not only reinforces that response, but occasions the next one in the chain. In both cases, the response produces the stimulus. In the latter laboratory case, this explicit contingency relationship (presenting grain whenever the peck is made) is under the control of the experimenter. In the former case, the contingency relationship (presenting sound whenever a vocalization is made) is under the control of sound-wave carriers in the environment. Breathing human subjects will have been exposed to such control from their first utterance (if they are not deaf). Natural though this contingency relationship to verbal behavior may be, the behavior is maintained by these stimuli in the same manner that behavior is maintained when the experimenter artificially schedules such a contingency relationship. Contingency delay (delayed feedback) by the experimenter is a method for finding the stimuli that maintain the behavior and usually elude the control necessary for such analysis. (Proprioceptive stimuli are the naturally established contingencies assumed to control behavior, but have thus far eluded explicit control.)

It was noted that when the controlling conditions were disrupted, verbal behavior was initially disrupted. However, this behavior was rapidly returned to the control of contingency relationships in whose presence it had been established. This was done either through prolongation of speech, which maintained control by the auditory presentation, or through control by nonauditory presentations, which had not been disrupted. Such control over the conditions can be considered a form of self-control. This type of control is characterized by situations in which the organism produces the stimuli that control further behavior, or eliminates them (*cf.* Azrin, 1961). This is precisely what occurs in ordinary speech governed by the "natural" contingencies discussed. However, this type of control is identical with the type exerted when the experimenter schedules the contingency relationship in chaining experiments. Hence, the analysis of self-control may be explicated by experimental attention to such operant behaviors.

Verbal behavior is under other environmental control. This has received greater attention than the "natural" control because it is more manipulable and more closely resembles explicit experimenter control. This involves social control, or control by an audience. The auditory stimuli that maintain the speaker's ongoing verbal behavior may also affect an audi-

ence; the audience may supply consequences, and this contingency relationship will also come to control verbal behavior (Skinner, 1957) and may enter into its maintenance. Accordingly, *two audiences may be involved in verbal behavior, one always being the speaker himself.* Self-control may also refer to behavioral control stemming from this relationship. Discrimination is established when behaviors in the presence of one stimulus are sometimes reinforced, but are never reinforced in its absence. The presentation of that stimulus may then control the response. If a verbal auditory stimulus comes to control a response through audience-supplied contingencies (for example, commands), that stimulus may also come to exert control when produced by the speaker himself (self-control). Hence, this dual audience characteristic of speech may account for its extensive use in attempted behavioral control.

Operant response classes are established when differing responses in the presence of similar stimuli receive similar consequences. Thus, the words *sweet, nice,* or *good* are in the same response class for drugstore cowboys, but are not synonymous in an English class. These are meaning or content classes. A characteristic of response classes is that manipulation of one member may similarly affect other members. Thus, a child slapped for saying a dirty word in company may not say other such words in company. Furthermore, reinstatement of two words in hitherto mute psychotics reinstated verbal behavior in general (Isaacs, Thomas, & Goldiamond, 1960). Much of psychotherapy is based upon the implicit assumption that verbal responses are in the same response classes as critical nonverbal responses. Response classes may be specific to the conditions under which they have been established. This condition poses a difficulty in psychotherapy, as well as in that type of self-control wherein the speaker produces stimuli that exert control over his responses when produced by others. The role of generalization in the extension of such control, and procedures for increasing it, are beyond the scope of this discussion (see Isaacs, Thomas, & Goldiamond, 1960). Having the stuttering subject define his own response was partly dictated by considerations relevant to generalization; that is, he could take the response with him. The second consideration is relevant to immediacy of reinforcement; that is, he could be more rapid in defining his blockage than could a monitor.

Breaks and pauses, repetitions, prolongations, and arhythmias are diffierent responses that are nevertheless classified as stuttering when they characterize a person's speech. Thus, these may be included in a response class for stutterers. Furthermore, this formal response class has been established in the same manner in which response classes are established in the laboratory, or in which content classes are established: Through similar consequences being applied to these differing responses, and different consequences being applied to other responses. The audience (or the experimenter) supplies such differential consequences, and accordingly defines and establishes response classes. This may be relevant to Johnson's (1955) observation that parents create the problem, or to Bloodstein's (1950) reports from stutterers who do not stutter to their pets. That stuttering sometimes runs in families may be related; if Uncle Henry stutters, Junior's fluencies and nonfluencies are far more likely to receive differential consequences than if there is no such familial history.

Making a fixed period of delayed side-tone contingent upon a stuttering response depressed the rate of this response class. This depression may be assigned to the aversive property (punishment) of such stimulation, as was evidently the case with the normally fluent subject whose button presses were attenuated. On the other hand, the depression may have been a function of the elimination by delay of the stimuli maintaining the stuttering response. In all events, the blockages tended to recover after these contingencies were eliminated. When delay was presented continuously but its elimination was contingent upon stuttering, the depressant effects seemed to be of such considerable duration and magnitude as to recommend their further study in the attenuation of stuttering. With Subject S, this schedule produced the prolongation of speech noted that when speeded up resembled the speech of some self-cured stutterers. With Subject K, this produced a new speech pattern within the normal range of nonfluency. Because stutterers report that they do not stutter when they sing or speak in a foreign language (Bloodstein, 1950), the stuttering pattern may be quite specific to its establishing conditions. Furthermore, these conditions may not have been present during the acquisition of singing, French, or the new patterns of the laboratory. What this schedule may be doing is to establish a new speech pattern in which stuttering has not

been embedded. However, it should be noted that noncontingent delay had only transient effects. These experiments raise questions that can be resolved only by further experimental anaylsis.

Although few subjects were used, the consistency of the data would seem to indicate their generality. In addition to the consistent effects just noted, noncontingent delay produced an initial decrement in reading rate, but there was recovery thereafter. In the elimination schedule, in which fluency is also accompanied by delay, the results were similar. When differential reinforcement was not applied to different reading rates, such behavior deteriorated. This raises the issue of explicit control and the maintenance of such monitoring behavior. The regularities in reading rate, especially under delay-listening conditions, suggest these as stable behaviors, deviations from which may be of interest. These are currently being investigated, as well as analysis of the stimuli stabilizing verbal behavior when auditory stimuli are disrupted.

The fact that content classes, or meaning, are established by the same means as formal response classes, suggests that an investigation of one may provide clues for the other. Content classes are difficult to define explicitly. Formal classes of speech are more amenable to definition and mechanical control through the scheduling of immediate response consequences. Accordingly, they lend themselves to experimental analysis and control, which may extend to analysis and control of content and meaning of those responses that may be the free human operants.

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